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IRON AND STEEL
ENGINEER
FUEL — ELECTRICITY — MACHINERY — METHODS
EMPIRE BUILDING, PITTSBURGH, PA.
To Educate the Engineer in Industry
APRIL, 1924
Containing the Proceedings of the A.I.&S.E.E.

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AUG 30 1924
DETROIT.

The Motor That Corrects Power Factor
By H. WEICHSEL
Chief Designing Engineer, Wagner Electric Corporation, St. Louis, Mo.

Power Generation In Modern Steel Works
By G. R. McDERMOTT
Mechanical Engineer, Illinois Steel Company, South Chicago, Ill.

Steel Mill Electrical Machinery and the Insulation Problem
By C. E. SKINNER
Asst. Director of Research, Westinghouse Elec. & Mfg. Company, East Pittsburgh, Pa.

Electric Power at Portsmouth Works of Wheeling Steel Corporation
By H. C. MOSLEY and R. H. ROGERS
Chief Electrical Engineer, Wheeling Steel Corp., Portsmouth, Ohio
Industrial Engineer, General Electric Company

Electricity In the Pipe Foundry
By JAMES W. MOORE
Chief Engineer, American Cast Iron Pipe Company, Birmingham, Ala.

Comparative Merit of Renewable Fuses
By A. E. ARTHURS
Sales Engineer, Bussmann Manufacturing Company, St. Louis, Mo.

Reversing Motor Driving 44" Reversing Blooming Mill.
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IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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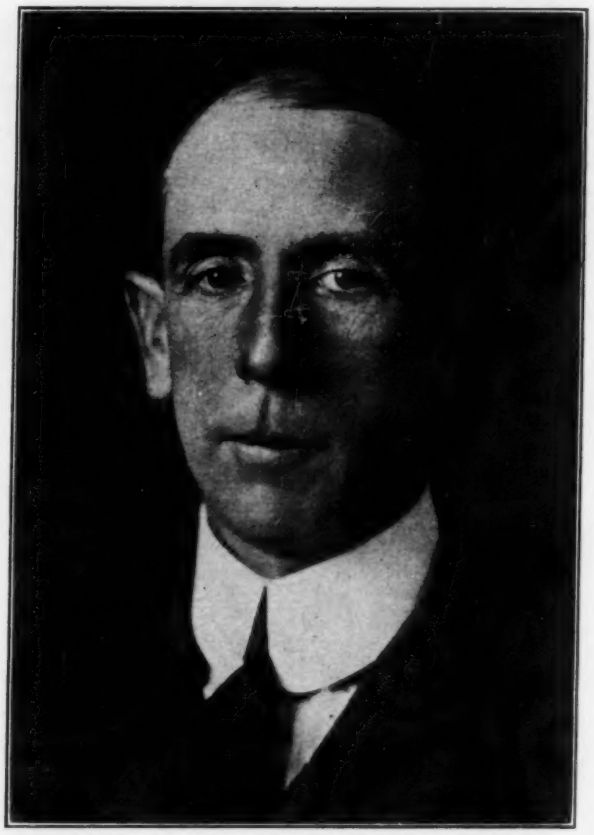
C. W. PARKHURST

Consulting Engineer, Berwind-White Coal Mining Company and Allied Companies



After graduation from Lehigh University, Mr. Parkhurst spent several years in the shipbuilding industry in America and abroad, in the electrification of the street railway surface system of New York City and with a large company manufacturing electrical apparatus.

He entered the steel industry in 1900 as electrical engineer and superintendent of the electrical department of the Cambria Steel Company, which position he held until 1917. During this period he made pioneer applications of hydro-electric power stations, transmission lines, electric hoisting, pumping and general power in the iron mines in the northern peninsula of Michigan; electric haulage, pumping and ventilating in coal mines in Pennsylvania and in steam turbine power plants, sub-stations and mill drives for steel mills and furnaces.

As consulting electrical engineer for Perin and Marshall, he had charge of the design of the steam turbine power station, sub-stations and mill drives for the greater extension of the plants of the Tata Iron & Steel Company of India; similar work for other interests in India, including a large hydro-electric power station and for a blast furnace and iron mining company in China.

Since 1917 he has been consulting engineer for The Berwind-White Coal Mining Company and allied companies, and his duties include the design and supervision of power stations, transmission lines, sub-stations, many of which are automatic, and machinery applications of all kinds to mines, docks and ships.

Mr. Parkhurst's activities with the Association of Iron and Steel Electrical Engineers dates back to October, 1908, when he became an active member. Served as Chairman of the Standardization and Papers Committee.

He was President of the A. I. & S. E. E. in 1913.

EDITORIALS

FUEL SAVING CONFERENCE

ABOUT 300 fuel and combustion engineers, representing practically every steel plant in the United States attended the annual fuel saving conference held under the auspices of the Combustion Engineering Section of the A. I. & S. E. E. in Pittsburgh, April 2 and 3, 1924.

The program was as follows:

Wednesday, April 2, 1924.

9:00 A. M. — Registration, Blue Room, William Penn Hotel.

9:30 A. M. — Address of Welcome—R. S. Shoemaker, President, A. I. & S. E.

9:35 A. M. — Purpose of Fuel Savings Conference —W. P. Chandler.

9:45 A. M. — Measurement of Input and Output of Boiler Rooms—By J. M. Spitzglass, Republic Flow Meters Co., Chicago, Ill.

11:00 A. M. — Ljungstrom Air Preheaters — By B. G. Brolinson, Engineer for Aktiebolaget Ljungstroms Angturbin, Wellsville, N. Y.

12:15 P. M. — Lunch — Blue Room, William Penn Hotel. Members and guests.

1:00 P. M. — Prevention of Scale Formation by Boiler Water Conditioning—By Dr. R. E. Hall, Physical Chemist, U. S. Bureau of Mines, Pittsburgh, Pa.; Light, Mesta Machine Company, Homestead, Pa.; and Mesta Machine Company, Homestead, Pa.; and George W. Smith, Chemical Engineer, Hagan Corporation, Pittsburgh, Pa.

2:15 P. M. — Topical Discussion. Coal Losses Due to Standby Steam Requirements and Demands.

3:00 P. M. — Inspection Trip — Allegheny County Steam Heating Company, Phipps Power Building, Duquesne Way, Pittsburgh, Pa.

6:00 P. M. — Dinner — Blue Room, William Penn Hotel.

Thursday, April 3, 1924.

9:30 A. M. — Heating Furnaces — By A. L. Culbertson, Manager, Chapman Stein Furnace Co.; Mt. Vernon, Ohio.

11:00 A. M. — Producers — By W. P. Chandler, Fuel Engineer, Carnegie Steel Co., Duquesne, Pa.

12:15 P. M. — Lunch — Blue Room, William Penn Hotel. Members and guests.

1:00 P. M. — Oxygen Enrichment — By F. W. Davis, Bureau of Mines, Washington, D. C.

2:30 P. M. — Inspection trip — Eliza Furnaces, Jones & Laughlin Steel Co. (One of the most modern power plans in the steel industry.)

Committee on Arrangements.

General Chairman, G. R. McDermott Assistant Chief Engineer, Illinois Steel Company, So. Chicago, Ill.

Secretary, W. P. Chandler, Fuel Engineer, Carnegie Steel Company, Duquesne, Pa.

Registration Committee.

F. E. Leahy, Chairman, Power Engineer, National Tube Company, Penna. Works, Pittsburgh, Pa.

M. J. Conway, Combustion Engineer, Wheeling Steel Corporation, Steubenville, Ohio.

W. J. Harper, Steam Engineer, Donner Steel Company, Buffalo, N. Y.

Reception Committee.

W. N. Flanagan, Chairman, Fuel Engineer, Carnegie Steel Company, Youngstown, Ohio.

F. G. Cutler, Chief Bureau of Steam Engineering. Tennessee C. I. & R. R. Co., Birmingham, Ala.

Plant Inspection Committee.

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L. C. Edgar, Chief Engineer, Carnegie Steel Company, Braddock, Pa.

C. R. Hunt, Chief Engineer, Weirton Steel Company, Weirton, W. Va.

J. C. Allen, Chief Engineer, Carnegie Steel Company, New Castle, Pa.

Papers Committee.

H. C. Seibert, Chairman, Combustion Engineer, Bethlehem Steel Corp., So. Bethlehem, Pa.

A. G. Witting, Assistant Chief Engineer, Illinois Steel Co., Gary, Ind.

Carl Fischer, Superintendent of Power, Mesta Machine Company, Pittsburgh, Pa.

J. W. Miller, Steam Engineer, Carnegie Steel Company, Clairton, Pa.

Mr. J. M. Spitzglass, of the Republic Flow Meters Company, at Chicago, Ill., presented a paper covering the Measurement of Input and Output in Boiler Rooms.

The author divided his subject into the following topics:

Part I — General information.

Flow versus Quantity Measurement.
Measuring Flow of Fluids.
Application of Measuring Device.
Installation of Differential Medium.

(1) Size of Orifice.
(2) Location of Orifice Plate.
  a. Standard Installation.
  b. Effect of Irregular Piping.
(3) Proper Spacing of Pressure Taps.
(4) Pressure Connections.

The Secondary Element of the Measuring Device.
Measuring Air Input to the Boilers.
Measuring Flow of Coal.
Part II — Determination of Constants.
General Outline.
Coefficient of Discharge.
Pipe Size Factor.
Scale Factor.
Density Factor.

(Continued on Page 194)

IRON *and* STEEL EXPOSITION

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FUEL SAVINGS CONFERENCE

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of

Iron and Steel Engineer

SUBJECTS

Air Preheaters.
Some Applications of Oxygen to Ferrous Metallurgy.
The Chapman-Stein Recuperator.
Measurement of Input and Output in Boiler Rooms.
Control of Pressure Gas Producers.
Prevention of Scale Formation by Boiler Water Conditioning.

Authors and Contributors to Conference

J. M. Spitzglass	Phillips Badenhausen	W. R. Little	Waldemar Dyrssen	F. W. Davis
J. B. Crane	A. G. Witting	Arthur Steed	C. Smith	Walter DeFries
F. M. Van Deventer	B. G. Brolinson	Dr. R. E. Hall	A .E. Miller	A. L. Milton
Strickland Kneass	R. S. Shoemaker	J. F. Tutein	B. R. Shover	Arthur Steed
F. G. Cutler	W. P. Chandler	J. B. Whitlock	F. E. Leahy	J. B. Whitlock
C. Fischer	W. N. Flanagan	A. C. Culbertson	J. B. Unger	W. R. Little
W. G. Knight	H. C. Siebert	W. C. Buell		

PHILADELPHIA SECTION

Invites

PITTSBURGH, CLEVELAND, CHICAGO, BIRMINGHAM DISTRICT SECTIONS

to participate in the

HARRISBURG MEETING

Friday, May 2nd, 1924—Saturday, May 3rd, 1924

PROGRAM

FRIDAY,	9 A. M. to 12 Noon	—Inspection and Luncheon, Bethlehem Steel Company, Steelton, Entrance Locust Street Gate.
	2 to 4 P. M.	—Inspection, Central Iron and Steel Company, Harrisburg, Pa.
	2 to 4 P. M.	—Inspection, Harrisburg Pipe & Pipe Bending Co., Harrisburg, Pa.
	6:00 P. M.	—Dinner, Ball Room, Penn Harris Hotel. Music by Employees Band of the Bethlehem Steel Co.
	8:00 P. M.	—Meeting, Paper by Dr. F. Herbert Snow, Seats on Floor, House of Representatives, State Capitol.
SATURDAY,	9:00 A. M.	—Inspection and Luncheon, Power Plant, Metropolitan Edison Company, Middletown, Pa.
	8:00 P. M.	—Inspection of Hershey, the Chocolate Town.

To the—Steel Industry, Mill Builders, Operating Superintendents, Engineers and those responsible for Steel Mill Tonnages.

ELECTRICALLY DRIVEN REVERSING MILLS WILL BE DISCUSSED

Saturday May 10, 1924—Pittsburgh, Pa.

Blue Room Wm. Penn Hotel

Technical Session 3 P. M. — Dinner 6 P. M. — Discussion 8 P. M.

Program of Papers and Meetings for District Sections of the A. I. & S. E. E.

Philadelphia Section

Officers and Committees—1923-24

Chairman—W. H. Burr.
Past Chairman—W. C. Kennedy.
Vice Chairman—P. T. Vanderwaart.
Executive Committee—W. H. Burr, chairman; P. T. Vanderwaart, W. C. Kennedy, F. H. Woodhull, George Pfeffer.
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Meetings Committee—B. T. Hare, chairman; T. E. Gallagher, C. H. Williams, C. J. Maloney, A. B. Coffman.
Reception Committee—George H. Schaeffer, chairman; L. R. Humpton, H. D. Esterly, H. G. Nichols, E. D. Sibley.
Membership and Attendance Committee — D. M. Petty, chairman James E. Wilson, H. N. Lucas, R. F. Gale, G. W. C. Frey.
Representatives to the Engineers' Club—Board of Directors, Linn O. Morrow; Meetings Committee, John C. Reed; Publications Committee, David Smith; Research Committee, H. A. Lewis.
Secretary—Linn O. Morrow, Franklin Trust Building, Philadelphia, Pa.

Meetings and Papers

Friday, May 2, and Saturday, May 3, 1924—
Harrisburg Meeting, Harrisburg, Pa.
"Decisions of the Public Service Commission Relative to Rates of Electric Light and Power Companies," Dr. F. Herbert Snow, Chief, Bureau of Engineering, Public Service Commission of the Commonwealth of Pennsylvania.
Inspection trips to the Steelton Plant of Bethlehem Steel Company, Harrisburg plants of the Central Iron & Steel Company and Harrisburg Pipe & Pipe Bending Company, Middletown plant of the Metropolitan Edison Company under construction.
Announcement of the results of the election of officers for the coming season.
Saturday, June 7, 1924—
Annual Outing. Details will be announced at the May meeting.
All meetings, unless otherwise noted, will be held in the Engineers' Club, 1317 Spruce Street, and will start promptly at 8 P. M. They will be preceded by an informal dinner at 6 P. M.
The privileges of the Engineers' Club are at the disposal of the members on the day of the meeting. Make the club your headquarters. Attend every meeting and bring your friends.

Pittsburgh Section

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Past Chairman—R. H. Keil.
Vice Chairman—R. E. Lewis.
Secretary—J. F. Kelly.
Assistant Secrtary and Treasurer—T. Moffitt.
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Papers Committee—R. E. Lewis, chairman.
Meeting Committee—W. C. McKibben, chairman.
Membership Committee—R. M. Hussey, chairman.
Entertainment Committee—E. W. Harry, chairman.

Meetings and Papers

May 10, 1924—
Electric Driven Reversing Mills by J. D. Wright, G. E. Stoltz and Rae W. Davis.
June 21, 1924—
Inspection Trip. (Via boat. One of the largest steel plants in the world; also one of the largest by-product coke plants in the world.)

Chicago Section

Officers and Committees—1923-24

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Vice Chairman—R. L. McIntosh.
Committeeman—W. S. Hall.
Committeeman—Gordon Fox.
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Reception Committee—Gordon Fox, chairman; O. M. Bercaw, L. M. Gumm, G. H. Lounsbery, E. C. Otto.

Meetings and Papers

May 16, 1924—
General ideas and discussions. Every active member is invited to prepare a short paper on a subject pertaining to the application of electricity to the iron and steel industry.

Cleveland Section

Officers and Committees—1923-24

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Papers Committee—S. L. Henderson, chairman.
Meetings Committee—H. W. Eastwood, chairman.
Membership Committee—C. B. Skelly, chairman.
Secretary—A. R. Lintern, 7960 Lorain Avenue, Cleveland, Ohio.

Meetings and Papers

May— Inspection Trip.

Birmingham Section

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Secretary—W. W. Garrett, Jr.
Papers Committee—L. M. Smith, chairman.
Entertainment Committee—J. E. Harrell, chairman.
Membership and Attendance—M. M. Argo, chairman.

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The Motor That Corrects Power Factor

By H. WEICHSEL*

ABOUT 40 years ago, the famous French physicist Monsieur Deprez determined by mathematical calculations that it must be possible to operate a 10 hp., d.c. motor over a transmission line about 30 miles long. His calculations showed that with a 4 millimeter telegraph wire for the transmission line, a 16 hp. dynamo would be required on the generating end.

A year later he demonstrated by actual tests during the electrical exhibition in Munich that his calculations were correct.

This was the signal for enthusiastic work among several engineers to attempt electric power transmission. Mr. Deprez himself returned to Paris and immediately started to construct a transmission line which he hoped would be capable of transmitting 250 hp. This experiment, however, was not successful. It showed, however, the importance of using high voltage for transmitting large amounts of energy over long distances.

The engineers in those early days realized that the easiest way for obtaining the necessary high voltage was by the use of a.c. instead of d.c., but no satisfactory a.c. motors were known them. In the meantime, a number of pioneers developed the d.c. transmission system to a fairly high degree of perfection with such voltage values as were available at that time. We are all familiar with the remarkable work which Mr. Edison did in this direction, and even today many systems or manufacturing plants exist which operate by direct current.

Not until after the invention of the polyphase system and the polyphase motor was it really possible to make full use of the necessary high voltages for long distance power transmission or for the transmission of large amounts of power. It seems appropriate to call attention to the fact that it was in Pittsburgh that Mr. Nicholas Tesla introduced and developed the polyphase motor and the polyphase system.

Soon after the introduction of this new type of motor and source of power, the electric power transmission operated by polyphase currents grew very rapidly.

While this system overcame one of the stumbling blocks of the old d.c. system—i.e., it was now possible to operate the system with very high voltages—it introduced, on the other hand, a new undesirable feature.

It was soon perceived that a polyphase transmission system operating polyphase induction motors required more current for a certain amount of energy than calculated by the formula: watt = volts per phase $\times$ phases $\times$ current per phase. For instance, in order to transmit a 1000 watts, which theoretically may require 1 ampere, it was found that say 1½ amperes were necessary in order to accomplish the desired result. The engineers called the ratio of the theoretical current for obtaining the desired energy to the actual current required the power factor.

In other words, in our example, this ratio is $\frac{1}{1.5}$, i.e., 66 per cent. Therefore, the system operated with 66 per cent power factor in our example. The power factor, therefore, means that under the most favorable conditions it should be possible to obtain the desired energy transmission with a current which is equal to the actual flowing current multiplied by the power factor.

The engineers at that period fully realized the importance of the power factor. They knew that the losses on the transmission lines would be a minimum if it would be possible to make the power factor unity and that the losses increase enormously with decreasing power.

For instance, in our illustration the losses of the transmission line could be reduced to $(.66 \text{ per cent})^2 = 43$ per cent of the actual losses if it would be possible to operate this transmission with unity power factor instead of 66 per cent.

This means that it would be possible to either transmit more energy over the same wire by using unity power factor or that for equal power transmitted it would be possible to decrease the amount of material required in the transmission system, i.e., in the wiring itself as well as in the transformers, switches, generators, etc. Also the regulation of the system is greatly improved if it is operated with unity power factor.

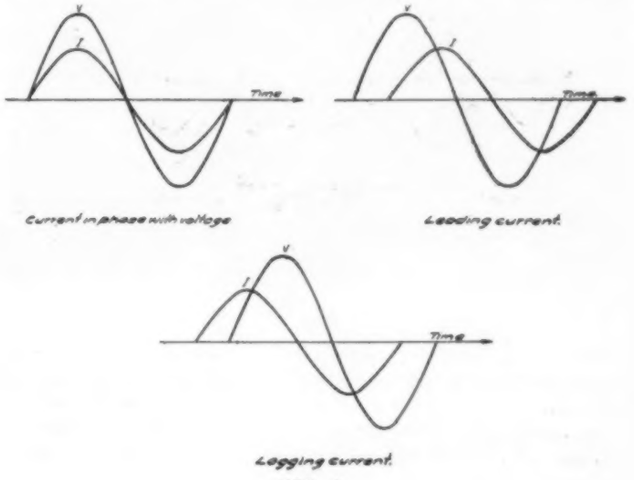


FIG. 1.

It was realized that physically the power factor is produced by the condition that in an a.c. circuit the current wave may not reach its maximum at the same moment at which the voltage wave reaches its maximum and that the current wave may reach its maximum earlier or later than the moment at which the voltage wave reaches maximum.

If the current wave reaches its maximum earlier than the voltage wave, we speak of the current as leading; and in the case where the current wave reaches its maximum later than the voltage wave, we speak of the current as lagging. A current with lagging power factor exists in electric transmission of the kind mentioned in the beginning.

*Chief Designing Engineer, Wagner Electric Corporation, St. Louis, Mo.

For unity power factor, the maximum of the current wave and the voltage wave occur simultaneously.

It is a well-known fact that if leading and lagging currents are drawn from a certain line, the leading current will have the tendency to neutralize the bad effect of the lagging current.

Attempts were made as far back as 1895 to overcome the undesirable characteristic of lagging current, inherent to the induction motor.

Mr. Le Blanc suggested sending a low frequency current into the secondary winding of the induction motor in order to obtain unity or leading power factor in the primary or line. Naturally, this required a separate low frequency generator.

A few years later, Mr. Blondel and Mr. Heyland proposed other ways of controlling power factor. None of their schemes have proved commercially successful, the reasons for these failures being that the methods were too complicated and it was necessary

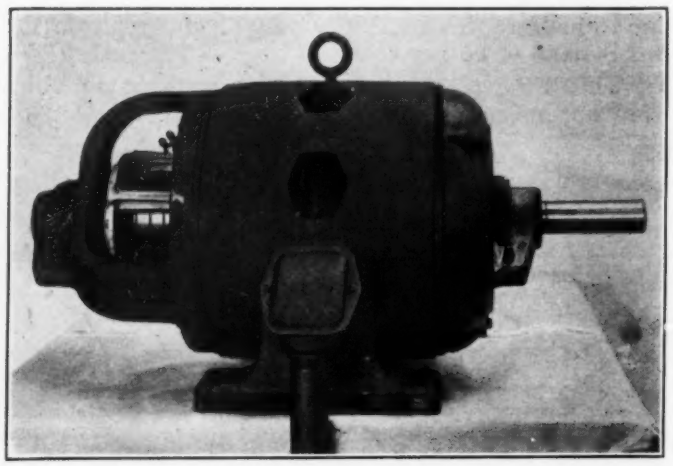


FIG. 2.

to commutate relatively large amounts of a.c. energy on the commutator of the machine proper or on the commutator of the separate exciter. The commutation is further made difficult because of these schemes commutating a.c. instead of d.c.

The only means which remained for obtaining improved power factor in these earlier days consisted in the synchronous motor, a machine which had, due to its characteristics, a rather limited field of application. The synchronous converter was also used to some extent for this purpose. The synchronous motor and the synchronous converter are two closely related machines.

Even today these two machines are practically the only rotating machines used in practice for correcting the power factor. Due to the continuous effort of the designers, it has been made possible to reduce many of the drawbacks which were found in the earlier type of synchronous motors. But even now we are confronted with the fact that these machines have starting characteristics which are not as perfect as may be desired.

In many of the installations with synchronous motors, it is necessary to use an external source of d.c. excitation. Also, friction clutches are frequently a necessity. The starting equipment is often of a complicated nature.

A number of years ago we designed a line of polyphase synchronous converters for transforming polyphase currents into d.c. These machines were built without pronounced poles for the d.c. field system. The stator of these machines was identical to the stator of the standard induction motors, i.e., there were no pronounced poles and the winding was distributed

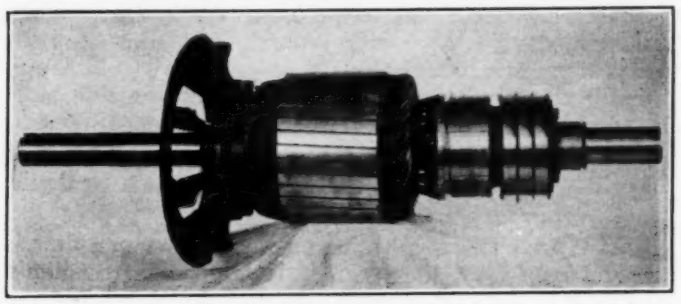


FIG. 3.

over the whole circumference of the stator bore and the air gap was uniform all around the rotor.

One day in the testing department we attempted to operate these synchronous converters as synchronous motors and discovered that the available mechanical power was considerably less than the d.c. energy which could be obtained when operating as synchronous converters.

The solution of the problem of improving the weight efficiency of this type of motor is the Fynn-Weichsel motor as described in this paper tonight. It has unity power factor at a selected load predetermined in the designing of the machine. In the machine placed on the market, the power factor is slightly leading at full load and is unity at about 150 per cent load.

As indicated, by suitable variation in winding design, the motor can be caused to operate at unity

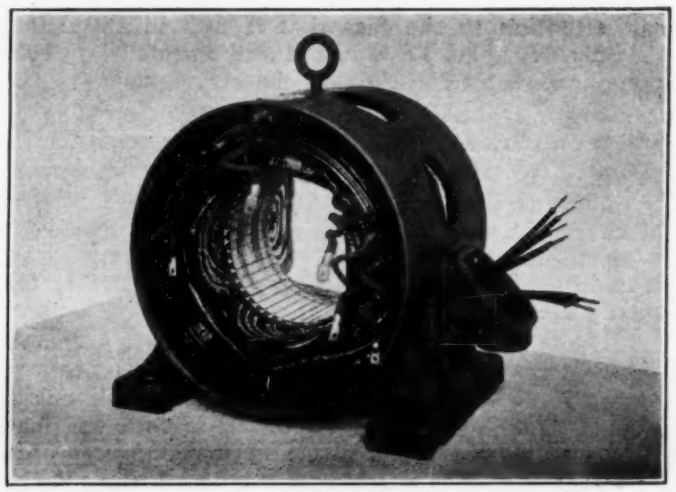


FIG. 4.

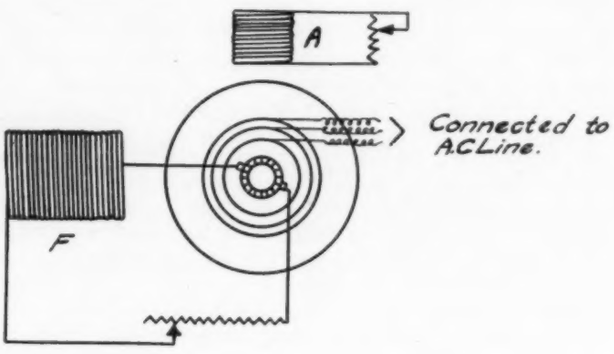
power factor at any desired point over a large part of the load range.

As will appear from Figs. 3 and 4, the Fynn-Weichsel motor is constructed without defined polar projections.

In a three-phase machine, the armature is provided with three slip rings, which are connected to a poly-

phase rotor winding. The slip rings are directly connected to the line.

Besides this main a.c. winding, there is a small d.c. winding on the rotor. This winding is connected to a commutator, and the commutator carries brushes which collect the small amount of d.c. which is required to excite the field of the machine.



Connection Diagram of Synchronous Induction Motor

FIG. 5.

The field system is shown in Fig. 4, and in general consists of a stator similar to a polyphase stator and is provided with two windings, one of which is the exciting winding and the other is used during starting period, as will be explained later.

The d.c. brushes in this new "self-excited synchronous induction motor" are not located in the same position as in a synchronous converter, i.e., the axis of the brushes is not vertical to the axis of the field exciting poles. Fig. 5 shows a suitable angular relation

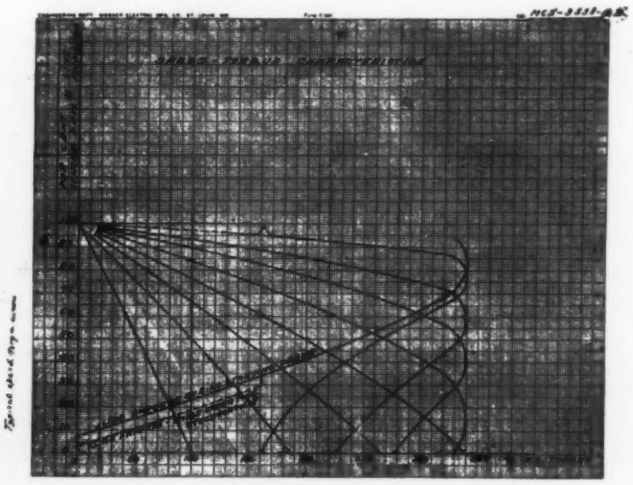


FIG. 6.

between the axis of the exciting winding and the brush axis.

The winding "F" in this figure represents the main d.c. field winding, while the winding "A" is an auxiliary winding. During the starting operation, the winding "A" is closed through a variable resistance. The winding "F" is connected in series with the commuted winding of the machine and is also closed over a variable resistance. This connection makes it possible to avoid any switching during the starting period. The only operation necessary is the closing of the line switch and the moving of the starter handle from off position to running position.

During the running period, the auxiliary or starting winding "A" is short circuited and under normal load does not carry any current, because, as pointed out in the beginning, this machine operates normally as a synchronous motor, and, therefore, no voltage can be induced in the winding "A".

Before continuing to describe the working characteristics of this machine, we will illustrate the starting performance.

Fig. 6 gives the speed torque characteristics of this machine when in starting connection. You will notice

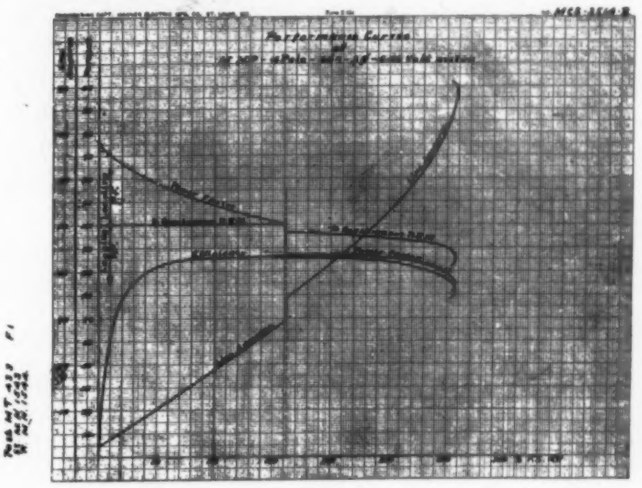


FIG. 7.

that the starting current required for starting full load torque is about equal to 1 to 1½ times normal full load running current of this machine.

In reducing the starting resistance, the speed for a given torque can be increased and finally, when the resistances are reduced to a very small value, a change in the speed torque character of the machine takes place. It will be noticed that when the resistance is short circuited and the torque reaches a value of 160 per cent or less, the machine changes its speed abruptly and jumps into synchronism. These phenomena mean that the machine is capable of starting and pulling into step a load of about 150 per cent with a current draw corresponding to that of an induction motor of similar design, an achievement which heretofore had been impossible in synchronous machines.

Naturally, after the machine has reached synchronous speed, it will continue to operate at synchronous speed for loads ranging from zero to about 150 per cent torque. When this torque is exceeded, the motor falls out of step as a synchronous motor and continues to operate as an induction motor. It will be seen from these curves that this particular motor was capable of carrying a maximum torque of about 340 per cent when operating as induction motor.

Fig. 7 shows the working characteristics of a 15 hp., 1800-rpm., 60-cycle Fynn-Weichsel machine throughout its load and speed range. You will notice

that the power factor of this machine is about 65 per cent leading at no load. With increasing load, the power factor approaches unity, and at 160 per cent load, the power factor has reached unity, and when motor is loaded beyond unity power factor, a point is reached at which the motor falls out of step as syn-

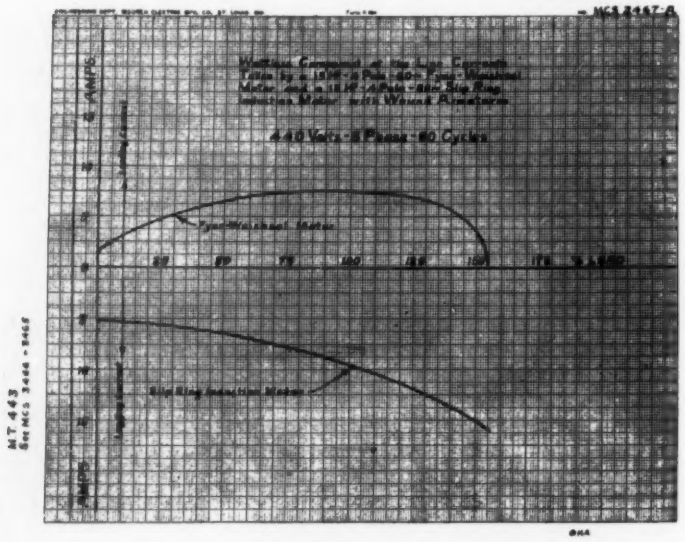


FIG. 8.

chronous machine. This can be seen from the curve marked "Per cent synchronous Rpm."

With further increase in load, the machine continues to operate, but as a polyphase induction machine. Its power factor is naturally no longer leading, but is lagging, because the machine now operates as induction motor. This will be seen from the curve marked "Power factor." The speed is no longer synchronous, but decreases with increasing load.

This particular machine can be loaded up to about 300 per cent before it ceases to operate as an induction motor.

The efficiency has characteristics similar to those of any standard polyphase induction motor. It increases rapidly with increasing load and then stays nearly constant over a large range of load.

The line current is rather interesting. In the beginning, it follows the expected laws of being somewhat proportional to the load, but as soon as the transition point is reached, i.e., where the machine goes from synchronous motor operation into induction motor operation, the current increases. This is caused by the change of the power factor from nearly unity to about 85 per cent lagging.

A remarkable feature of this machine is its leading power factor over the whole normal working range. For instance, at full load this machine has 92 per cent leading power factor.

As stated above, machines taking a leading power factor have the ability of correcting the lagging power factor taken by standard induction motors. By properly selecting the amount of leading Kva. taken by the Fynn-Weichsel motors and the lagging Kva. taken by induction motors, it should, therefore, be possible to obtain practically unity power factor over a large range of loads on the line supplying these motors.

A clear inside view of this condition is probably obtained by Fig. 8, which shows the leading Kva. taken by a 15-hp., 1800-rpm., Fynn-Weichsel motor and the lagging Kva. taken by an equivalent 15-hp. slip ring induction motor. It will be noticed that the new "self-starting synchronous induction motor" takes approximately as much leading Kva. as the equivalent standard induction motor takes lagging Kva. over a large load range, practically from half load to 1¼ load.

Therefore, it should be expected that if both these motors are operating in parallel on the same circuit the resultant power factor should be nearly 100 per cent. The actual result of two of these machines operating in parallel has been given in Fig. 9, which shows that the power factor on the line of a 15-hp., 1800-rpm., slip ring induction motor and a 15-hp., 1800-rpm., Fynn-Weichsel motor when operating from the same line and both being equally loaded is practically constant over the whole working range.

The machines as shipped at present are all designed to agree in general with the characteristics just shown, i.e., with leading power factor over the whole working range.

It is possible, however, to modify the design in such a manner as to make the power factor nearly unity over practically the whole working range. This particular design of machine might become of importance in the future, after the present trouble of lagging power factor in the circuits has been banished, because if under those conditions machines are added which have leading power factor, we will obtain a condition in the line which again has a power factor different from unity, and in this case the circuit would operate with leading power factor. A condition of leading power factor in the line is at least as bad, if not worse, than a condition of lagging power factor in the line.

In all possibility, however, it will be quite a while before the condition has been reached that the circuits are operating under unity power factor, and that, therefore, no machinery with leading power fac-

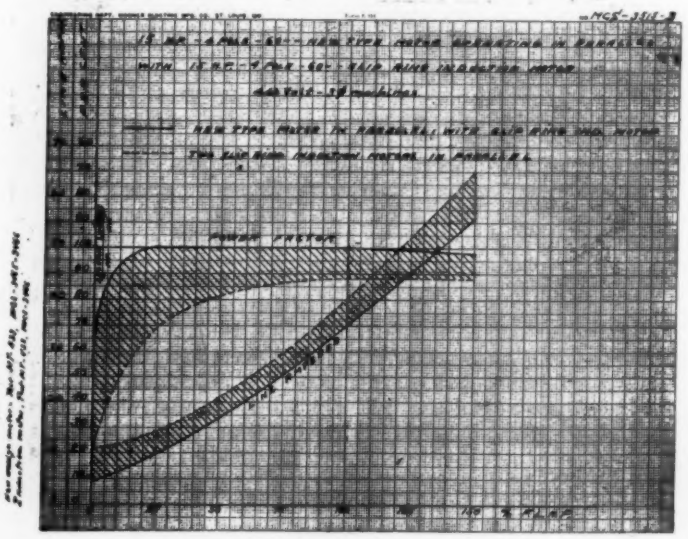


FIG. 9.

tor should be added. But when this time arrives, we are in a position to furnish these machines with a design for practically unity power factor over the whole working range.

From the operating point of view, it will be of greatest interest to know how this machine behaves

when voltage, frequency, or perhaps changes in the resistance of the exciting circuits occur.

The following slide will show the influence of ohmic resistance in the exciting circuit. These curves represent tests on a somewhat later design than the curves we have just viewed. Notice that in this design we have even been successful in making the maximum which the machine can carry as synchronous motor even larger than that of the machine whose performance has just been shown.

Curve 1 in Fig. 10 shows the power factor of the machine when resistance is connected between the d.c. exciting winding and the d.c. brushes. In most installations, as a rule, a certain amount of wiring is needed between the motor and its controller, and as one phase of the controller is connected in series with the exciting circuit, it is natural that a certain amount of external resistance will be found in the exciting circuit.

Curve 2 shows the power factor of the same machine when a resistance of .1 of an ohm is introduced

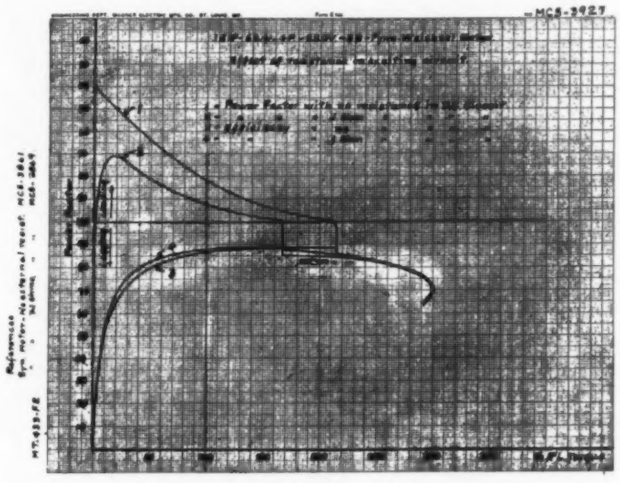


FIG. 10.

in this exciting circuit. You will notice that the power factor at no load is about unity and then with the lightest amount of load the power factor reaches about 70 per cent leading, and from there on approaches unity until it finally reaches 100 per cent, when the machine comes near its "breakdown point as synchronous motor", or as this point is frequently called, "the transition point".

These curves further show the influence of the resistance in the field circuit on the maximum load which the motor can carry as synchronous motor. With the minimum resistance in the circuit, the maximum hp. is a maximum and with increasing resistance the maximum hp. as synchronous motor decreases. However, the maximum torque of the machine operating as induction motor is practically independent of the resistances in the exciting circuit. This can be seen from the righthand part of the curves.

The efficiency is slightly influenced by the resistance in the exciting circuit, and it is interesting to note that with .1 ohms external resistance in the exciting circuit, the efficiency is slightly above the value which exists when no external resistance is connected into field circuit. The change amounts to about 1 per cent at full load.

The explanation for this change is easily seen if we refer to curves 1 and 2, which show that with .1 ohms resistance on the circuit, the power factor is nearer to unity than with no resistance in the external field circuit. Therefore, with resistance in circuit, the

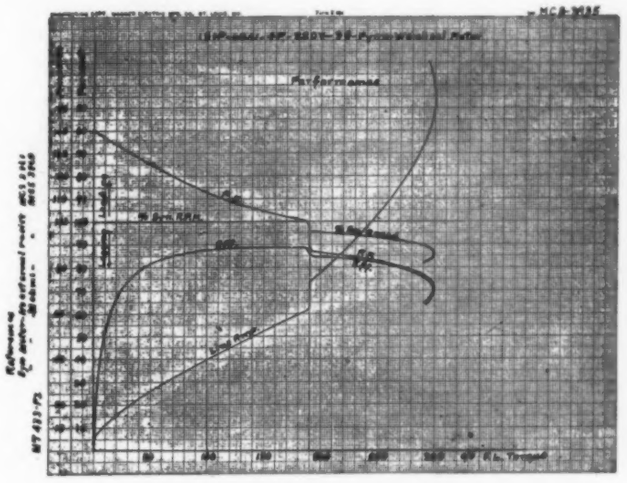


FIG. 11.

current draw of the machine decreases and, therefore, the copper losses in the machine decreases. But as seen from the curves, the influence is rather small.

A resistance of .1 ohm for the wiring between motor and controller is higher than will be found in most commercial installations and usually the resistance will lie in the neighborhood of about .05 of an ohm. Under these conditions, the machine just discussed will have the performance as given on Fig. 11. Generally speaking, the power factor, efficiency, etc., curves lie approximately half way between the two extremes shown on the previous figure. This curve represents the characteristics of a 15-hp., 4-pole, 60-

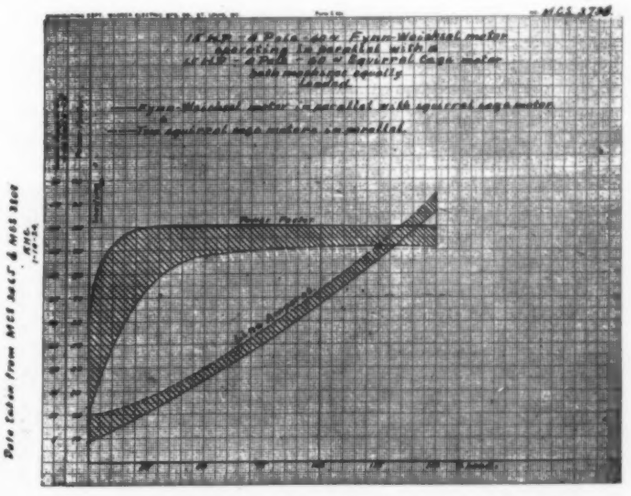


FIG. 12.

cycle machine built by us at present, and you will see that its breakdown point as synchronous motor lies in the neighborhood of 190 per cent.

It will be interesting to note the influence which this type of machine would exert on the power factor

of the system if an installation which consists of this type of motor and of standard induction motors.

Fig. 12 shows conditions which exist when a 15-hp., 4-pole, 60-cycle, squirrel cage induction motor is operating in parallel with a 15-hp., 4-pole, 60-cycle Fynn-Weichsel motor with the characteristics just described. Both motors are assumed to be equally loaded. It will be noticed that the power factor is practically unity over the whole working range and only at very light loads, below 25 per cent, is the power factor lagging. But it is known that it is almost impossible to load any machine less than about 25 per cent, as usually even the idle belt load is sufficient to exceed this load.

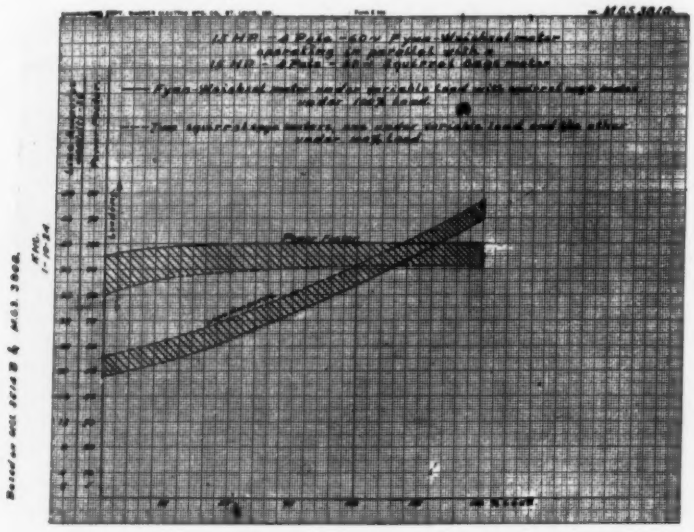


FIG. 13.

These curves show the large gain in line power factor. The gain over the value existing when two squirrel cage motors are used is indicated by the shaded area.

The improved line power factor is naturally reflected in a marked decrease in current draw. The dotted curve shows the current draw which would exist when two squirrel cage motors are running in parallel, both equally loaded, and the heavy line represents the current draw which exists when one squirrel cage motor and Fynn-Weichsel motor of same capacity are operating in parallel, each equally loaded.

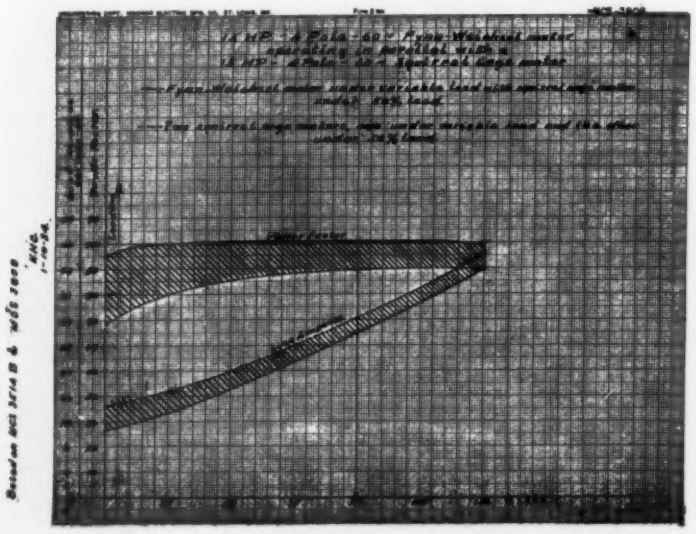


FIG. 14.

It might occur, however, that in practice both motors are not equally loaded. A picture of the relations which exist under these conditions can be obtained from the following curves:

Fig. 13 assumes that the squirrel cage motor is loaded with a constant load of 100 per cent and that the load on the Fynn-Weichsel motor is variable. The curves are drawn up for variable load from no load to 150 per cent. It will be noticed that the power factor is practically 100 per cent over the whole working range.

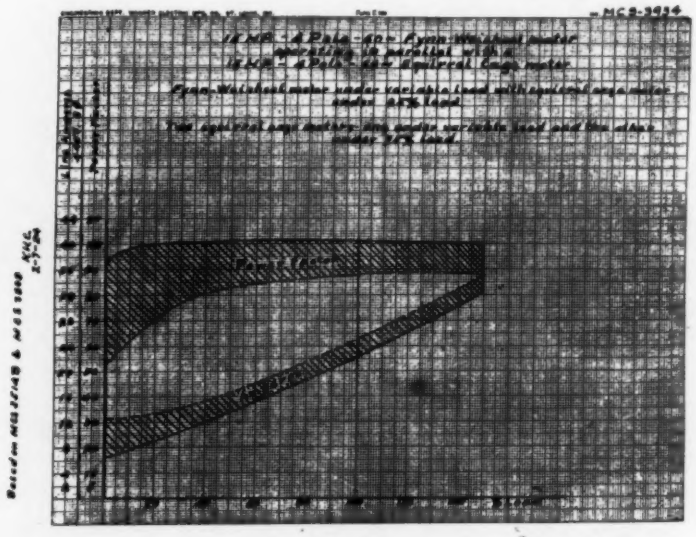


FIG. 15.

If, on the other hand, the Fynn-Weichsel motor would be replaced by a squirrel cage motor, i.e., the load of one squirrel cage motor is kept constant at 100 per cent while the load on the other squirrel cage motor is varied from zero to 150 per cent, we will obtain the conditions as indicated by the dotted lines, and the difference between the dotted lines and the solid lines, which is indicated by cross-etchings, represents the gain in power factor as well as in current by using a Fynn-Weichsel motor in place of one of the squirrel cage motors.

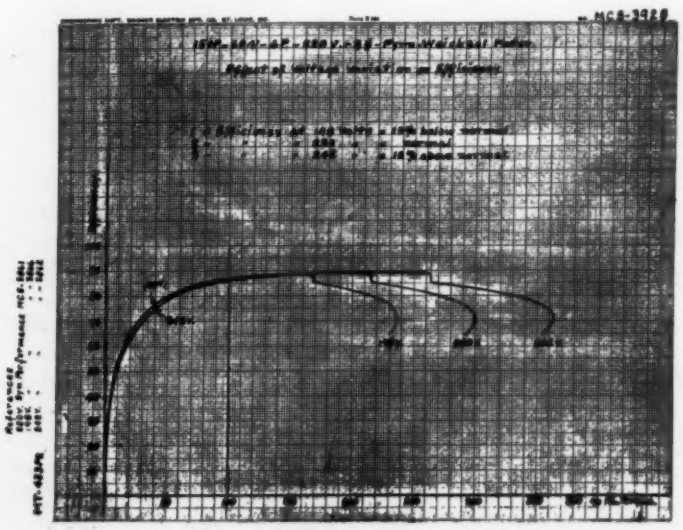


FIG. 16.

Similar conditions have been represented in Fig. 14 for the case that a squirrel cage motor is operating at 50 per cent normal load and is connected in parallel to a Fynn-Weichsel motor when load is raised from no load to 150 per cent. Again you will find that the power factor is constant over the whole working range and is practically unity, and consequently the line current is materially reduced.

A third condition is given in Fig. 15, in which the squirrel cage motor is assumed to be loaded only 25 per cent while the load on the Fynn-Weichsel motor operating in parallel is varied from no load to 150 per cent load. Even under these light load conditions, the power factor is practically unity over the whole range and is materially above the value which would exist if the installation would consist of squirrel cage motors only. Also the current draw from the line is materially reduced.

These curves give a representative view of the conditions which will exist in an installation when equal hp. capacity of Fynn-Weichsel motors and squirrel cage induction motors are installed and they show that under these conditions substantially unity power factor can be expected.

If it is not deemed necessary to raise the power

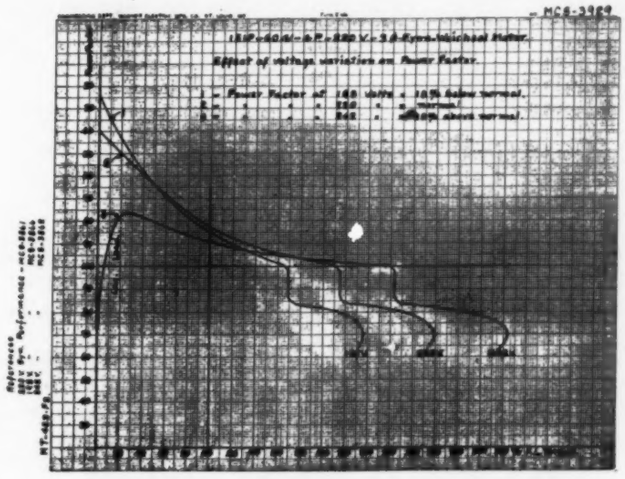


FIG. 17.

factor to 100 per cent, then it would be advisable to operate, let us say, with 75 per cent squirrel cage motors and 25 per cent Fynn-Weichsel motors. Under these conditions, the resultant power factor will be in the neighborhood of 90 per cent.

The next point of interest is the influence of voltage variation on the performance of this new self-starting synchronous motor. It is generally accepted that a line voltage variation of plus or minus 10 per cent is allowable.

Fig. 16 shows the influence of 10 per cent line voltage variation on the efficiency and on the maximum torque of the machine. It will be noticed that the efficiency is very little influenced, while the maximum torque which this machine can carry as synchronous motor varies approximately with the square of the voltage. Also the maximum torque which this machine can carry as induction motor varies approximately with the square of the voltage. In other words, variation in line voltage effect the machine in a similar manner in which the polyphase induction motor is effected.

Fig. 17 represents the influence of voltage variation on the power factor. Curve 2 shows the power factor under normal working conditions. With increasing voltage, the power factor comes nearer to

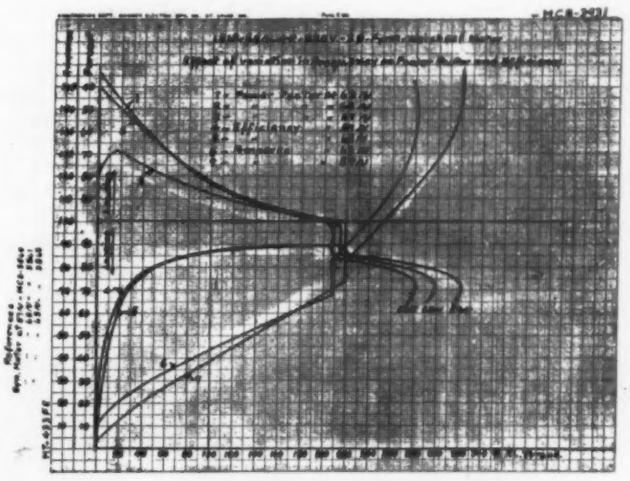


FIG. 18.

unity over a large part of the working range, as seen by curve 3. You will see that from about 5 per cent load upward, the power factor is leading and that the breakdown torque, as already shown, has increased over its value corresponding to normal operating voltage.

With 10 per cent below normal voltage, the power factor at no load is more leading than under normal voltage conditions. When full load is reached, the power factor is slightly less leading than under normal voltage conditions. Generally speaking, we can conclude from these curves that with increasing volt-

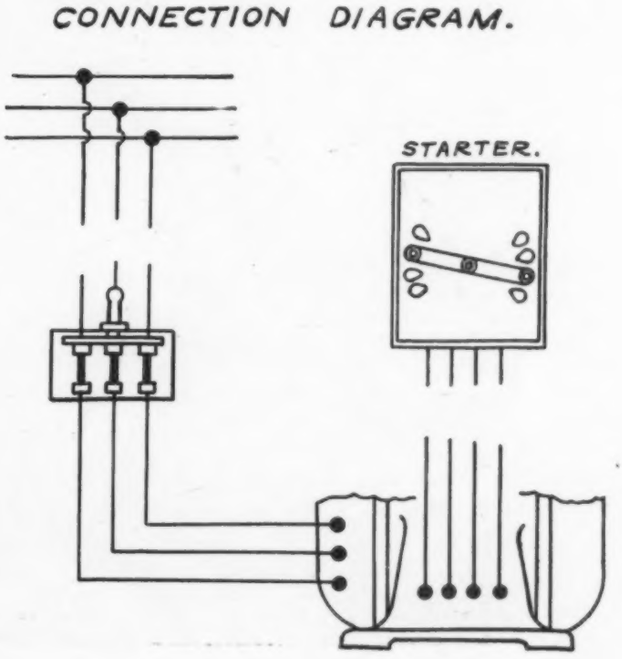
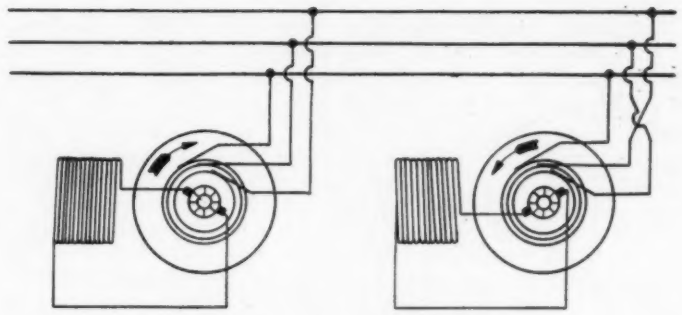


FIG. 19.

age the leading power factor approaches more unity and that with decreasing voltage the leading power factor moves more and more away from unity.

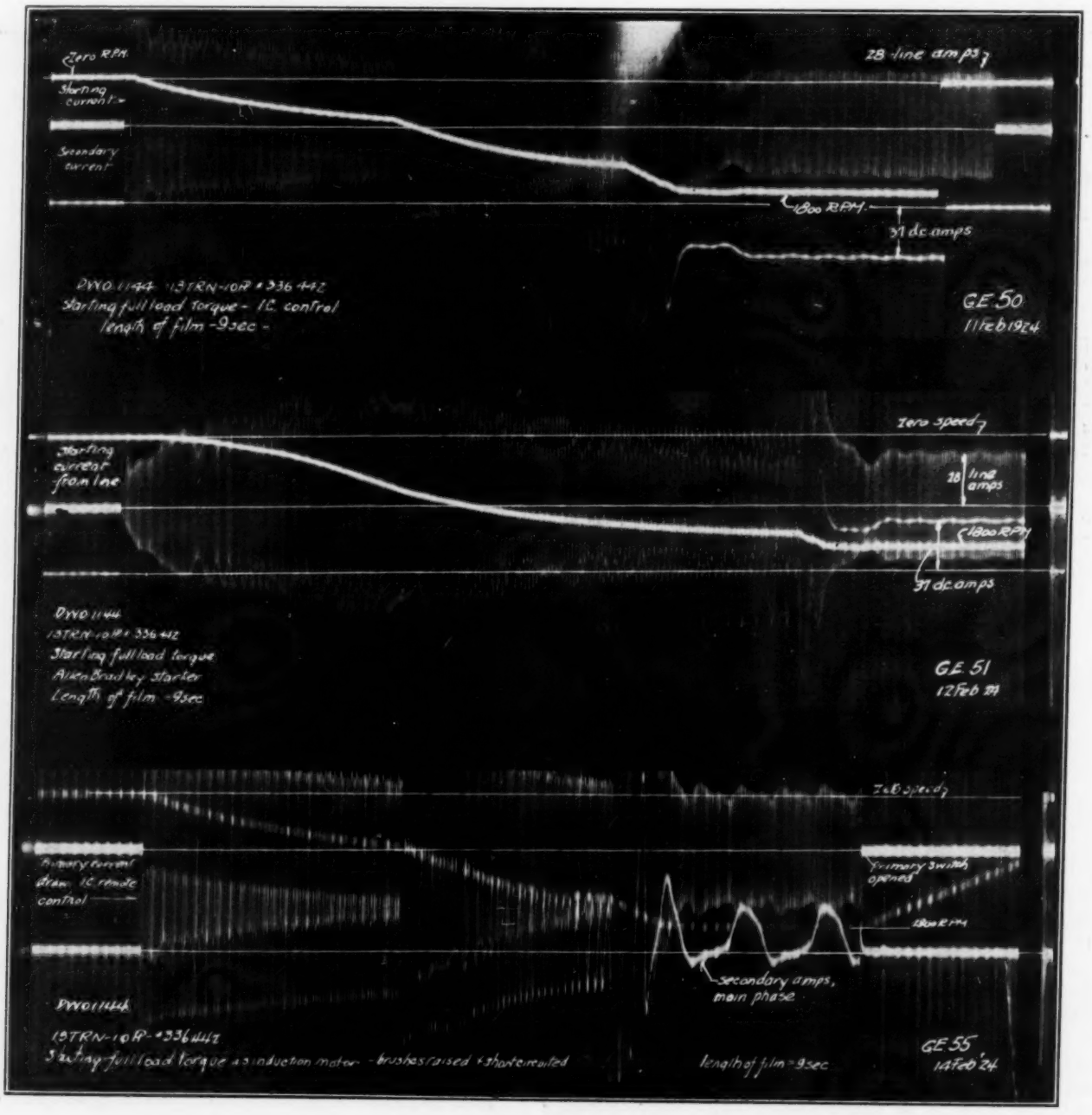
This is a rather desirable condition, as it has a certain correcting effect on the circuit. If the voltage is high, we desire less leading component, because the less leading component we have the greater the voltage drop. Therefore, the tendency of this type of machine is to have a certain amount of self-correcting effect on the voltage regulation of the circuit.

Another variation which is liable to occur in installations is a change in frequency. On Fig. 18, test results are given on the 15 hp. machine when operating under normal voltage and with frequencies of 63, 60, and 57. The first striking feature of this slide is the change in maximum torque. With increasing frequency, the torque decreases. This again is exactly the same as will be found in a standard induction motor. This decrease in torque not only refers to the Fynn-Weichsel motor when operating as an induction motor but also when operating as synchronous motor. The efficiencies are, broadly speaking, uninfluenced by plus or minus 5 per cent variation in frequency. However, there is some influence on the power factor.



Method of reversing direction of rotation of Synchronous Induction Motor.

FIG. 20.



FIGS. 21 and 22.

With decreasing frequency, the power factor has a tendency to be nearer to unity. The change in frequency acts very similar to the change in voltage, i.e., decreasing frequency corresponds to increasing voltage and increasing frequency corresponds to decreasing voltage. It will be seen that this law is exactly the same as the one which exists for standard induction motors. This curve further shows that the line current is influenced by the change in frequency. This change in line current is the natural result of the change in power factor. With decreasing frequency, the line current decreases over the normal working range.

We have now discussed the main features of this machine when operating under variable circuit conditions, as might occur in practical operation. A few words regarding the installation and handling of this type of machine might be appropriate.

Fig. 19 shows the connection of this motor to its controller. You will notice that the machine is in principle wired in exactly the same manner as a standard slip ring machine, with the exception that the secondary circuit is a two-phase circuit with four wires against the usual three-phase circuit found in slip ring induction motors.

The machines sent out from the factory are set for counterclockwise rotation, in accordance with power club rules. If it should be desired to operate the machine in clockwise rotation, it is necessary to do two things (see Fig. 20)—(1) to reverse the wires from the line to the slip rings of the motor in such a manner as to change the direction of rotation—in exactly the same manner as in any standard induction motor. (2) The rocker arm has to be moved from the position marked right hand to the position marked left hand. The change in position of the rocker arm amounts to only a few mechanical degrees.

The starting equipment of the machine is in every respect similar to the starting equipment of a standard slip ring induction motor. The starters are provided with no voltage relay and maximum current relay so as to protect the machine against abnormal load or line conditions. If desired, the machine can be started by push button control, i.e., an automatic starter can be used in connection with this machine.

The upper part of Figs. 21 and 22 shows an oscillogram taken on a 15-hp. motor when started under full load by a push button control. This particular starter had its switches controlled by a dashpot, but this method of control is not essential. Any control, such as current, time, or voltage control is feasible. This oscillogram is particularly interesting, as it not only shows the acceleration of the machine but also shows the currents flowing in the line circuit as well as in the exciting circuit. As can be expected from the construction of this machine, the frequency in the exciting circuit is equal to the frequency in the line when the machine is at standstill, and the frequency of the exciting circuit decreases with increasing speed and finally goes over into no frequency, i.e., d.c. This condition exists when the machine is operating at synchronous speed.

It is extremely interesting to note from this oscillogram the relatively small disturbances which occur on the line during the whole starting period. Special attention should be called to the fact that this machine was started under full load condition from rest to synchronous speed, and it is a peculiar feature of this type of machine that it has a very heavy synchronizing torque.

The oscillogram in the center of 21 and 22 represents a condition, which was purposely obtained, where the rotor was not up to constant speed at the moment the short circuiting of the last step of resistance occurred. Due to this, the rotor slipped 25 per cent at the last switching moment.

The oscillogram shows that motor has sufficient synchronizing power to pull itself into step from 85 per cent speed when full load torque is on the motor. The current draw at this moment of "pull-in" does not differ materially from that which would occur in a standard slip ring motor under otherwise equal conditions.

The upper figure on this slide shows the same machine started under otherwise equal conditions, but the automatic starter has been replaced by a manually operated starter. In this case a finer graduation of the resistances is possible, and, therefore, at the moment of short circuiting the resistance, the motor operates with less slip than in the case of the automatic starter and consequently the current in-rush at this moment is still less than in the case of the automatic starting device.

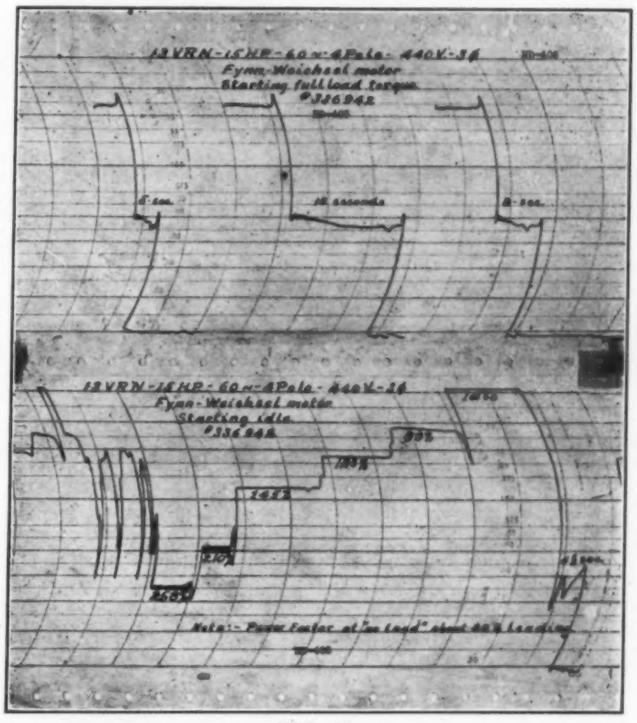


FIG. 23.

The bottom of Figs. 21 and 22 shows the starting conditions of an induction motor with the resistance starter in the secondary. The starter is of the remote control type. It will be noticed that the general appearance of this oscillogram and the oscillograms in the center of the cut is very similar. This excellent "pull-in" torque has been obtained by locating the d.c. brushes nearly in axis with the field winding.

It was theoretically derived that under these conditions a very heavy "pull-in" torque must occur. The reason for this is that the voltage induced in the exciting circuit and across the brushes must at any mo-

ment be of equal frequency, because in the exciting circuit or secondary of the machine the frequency is determined by the speed of the resultant rotating field against the secondary winding; and the frequency across the d.c. brushes is determined by the speed of the rotating field in respect to the brushes, and as secondary winding as well as d.c. brushes are station-

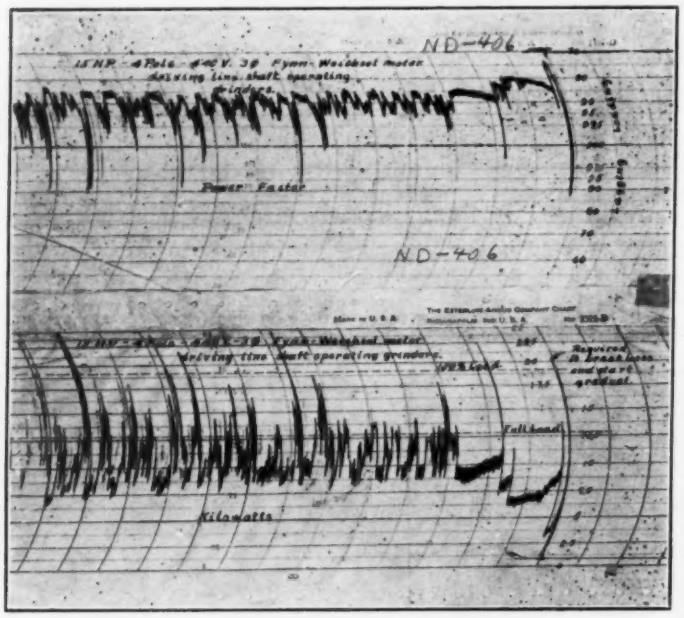


FIG. 24.

ary, it follows that the frequency on the brushes at any time must be equal to the frequency of the exciting circuit.

The phase relation of the low frequency voltage across the commutator brushes will depend on the position of these brushes in space and when the brushes are so located that their axis coincides with the axis of the exciting winding then the low frequency induced in the exciting winding is in phase with the low frequency voltage generated across the commutator brushes. Therefore, if the exciting circuit is so connected in series with the armature brushes that the two voltages in the exciting circuit and the brush circuit add to each other, it follows that a current must at any time flow in this circuit which is larger than the current which would flow if the secondary circuit would be short circuited in itself. But a larger current flow for a given speed must naturally be followed by an increased torque for this speed, and this in turn simply means that the location of the brushes near the axis of field winding must result in a heavy pull in torque. Of course, placing the brushes in the axis of the exciting winding results in the highest possible value of pull in torque, but such location is not so favorable with respect to power factor since a neutralizing component of magnetization exists only when the armature reaction flux has shifted from the brush axis under load.

Before closing, a few graphic records on a machine under actual working condition might be of interest.

Fig. 23 shows a power factor record as obtained on a motor operating under different load conditions. The first part of this curve shows the starting conditions of the machine when starting under full load. In this case, the starter is manually and not automatically operated.

During these tests, the handle of the starter was in one case moved from off position to full load speed position in a period of 5 seconds. In another case, the handle was moved considerably slower and 19 seconds were consumed for the starting period, and in the last case, the starting period was made 8 seconds.

The striking feature in all these three records is the power factor of the machine during the starting period, which lies in the neighborhood of 85 per cent to 90 per cent lagging, and as soon as motor has reached synchronous speed, the power factor reaches a value of about 86 per cent leading.

The small hook on the power factor curves are produced by the inertia of recording instrument needle and have no meaning regarding the operation of the motor.

The lower figure on this slide represents the motor operating under different load conditions, and shows the power factor corresponding to these loads. It also demonstrates the starting of the machine which in this case lasted 4½ seconds.

Fig. 24 shows graphic records of power factor and Kw. input of a 15 hp. motor operating a bank of grinders. The outstanding feature in these records are the frequent heavy peak loads which pull the motor out of synchronism, and as soon as this load has eased up the motor went back into synchronism and furnished leading current.

DISCUSSION

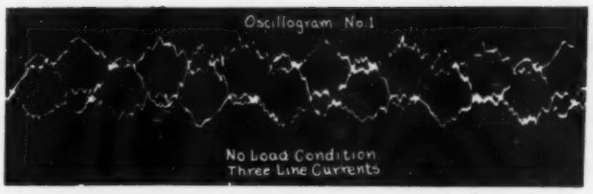
H. E. Dyche*: No one here tonight appreciates better than I do the rather delicate position in which I am placed. It must be clearly understood, therefore, that I, as well as the operating company for whom these tests were made, occupy an independent position in this matter.

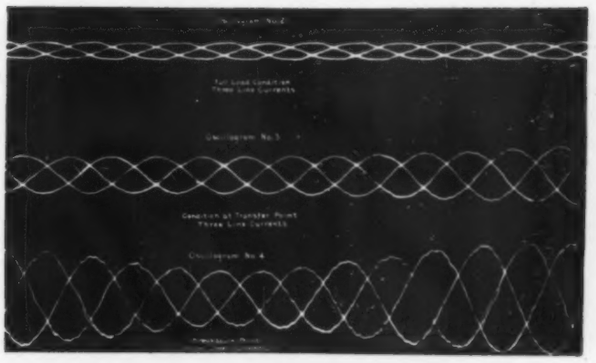
The tests which we propose to discuss were made on a 15-hp., 220-volt, Fynn-Weichsel motor, manufactured by the Wagner Motor Corporation. These tests were made in the University of Pittsburgh at the request of one of the large operating companies, with a view to determining line conditions with motor operation of this type. Through the courtesy of this operating company, the results of these tests are being presented at this time for your discussion. For the reasons indicated, the study has been limited more or less to external operating conditions. Could we have anticipated the present use of these data it would have been possible to have obtained a number of oscillograms showing in greater detail the motor operation under varying conditions of adjustment, service, etc.

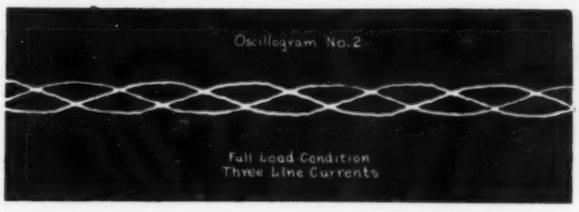
Fig. 25 shows the performance curves obtained on the 15-hp., 220-volt motor in the laboratory test. The loading was by means of a prony brake. This method gives very reliable results in those sizes which permit the use of a brake. Curves are given for speed, power factor, efficiency, torque, line amperes, d.c. field amperes, and kilowatt input; all meters being calibrated after the test.

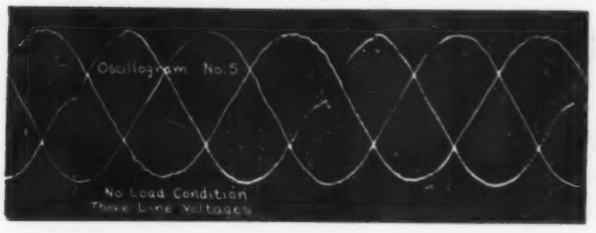
Four loading points have been considered throughout for the purpose of discussion. No load, full load, transfer point at 183 per cent load and pull out point at 260 per cent load. The transfer point, as indicated, occurs at unity power factor, and is that point at which

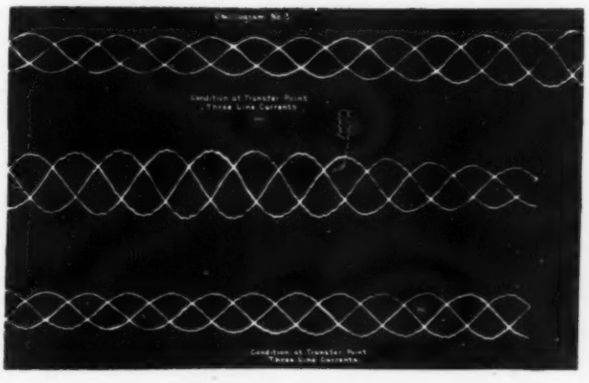
*Professor and Head, Department of Electrical Engineering, University of Pittsburgh.

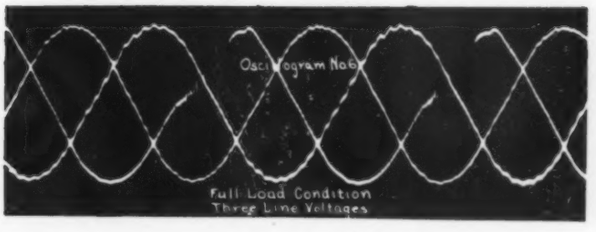

Oscillogram No.1
No Load Condition
Three Line Currents

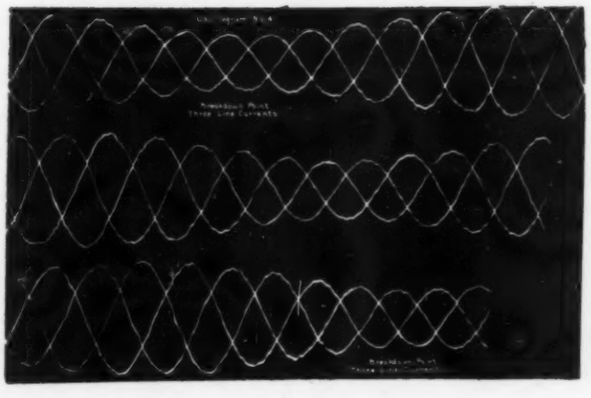



Oscillogram No.2
Full Load Condition
Three Line Currents

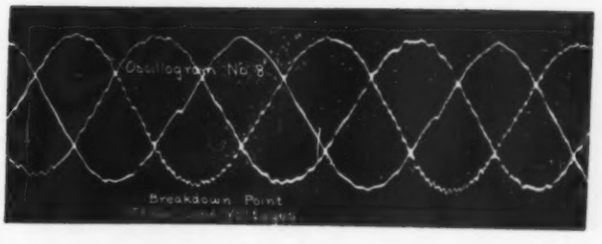

Oscillogram No.5
No Load Condition
Three Line Voltages




Oscillogram No.6
Full Load Condition
Three Line Voltages



Oscillogram No.7


Oscillogram No.8
Breakdown Point

synchronous motor action ceases and induction motor action begins. The pull out or break down point is similar to that occurring in any induction moter test. With the exception of the leading power factor curve all the curves up to the transfer point are similar to those obtained in any induction motor. The motor operation at and above the transfer point is unique because of the surging of gradually increasing frequency, the electrical characteristics of which will be shown later. The torque however during these surges is perfectly uniform. The efficiency of the motor is 80 per cent at full load, with a maximum efficiency of

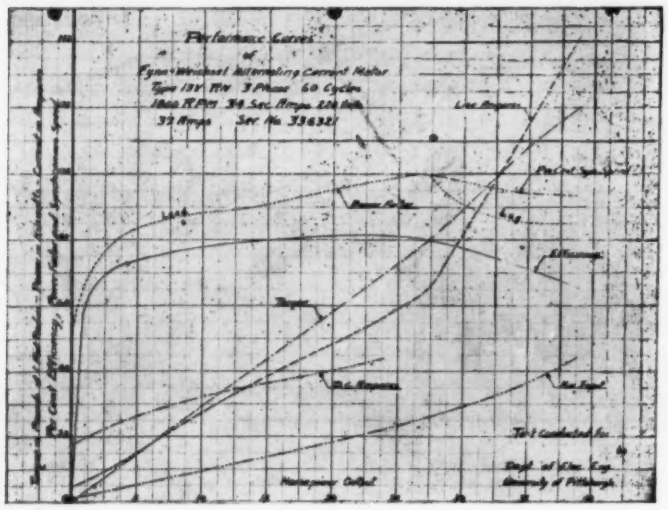


FIG. 25.

approximately 82 per cent at 150 per cent load. The manufacturers show somewhat higher efficiencies in their published data. The Wagner publication is quite general in that they refer to no specific size but perhaps a general line of motors. The larger size motors will of course produce higher efficiencies.

Oscillogram No. 1 represents the distorted no load current on the motor, the ragged and distorted appearance indicating the predominance of exciting current typical in lightly loaded induction motors and transformers. The effective value of the wave is equivalent to 4.5 amperes.

Oscillogram No. 2. This represents the three line currents at full load and require no particular comment. The effective value of the wave is 38 amperes.

Oscillogram No. 3, showing the three line currents taken at the transfer point is of particular interest in that it shows the beginning of the surging referred to before. The reasons for this action will be more apparent in a subsequent slide. This surge should not be confused with the harmonic oscillations commonly referred to, but might properly be termed a mechanical-electrical surge.

Oscillogram No. 4. This shows the three line currents near the pull out point and quite similar to those at the transfer point except the surges occur more frequently, about every 1/12 of a second. The variation in the amplitude of the line current is shown in the performance curves previously shown, by the abrupt departure of the line amperes curve from a straight line at the transfer point. The amplitude of the current from maximum to minimum varies by approximately 200 per cent.

The next illustration represents a section from each of the three preceding slides for the purpose of comparing the current waves at full load, the transfer and pull out points.

Oscillogram No. 5. This shows the three line voltages under no load conditions. The point of particular interest in the voltage waves is the high frequency oscillation in one of the three phases. This oscillation in the no load wave is of variable amplitude changing from zero to approximately 100 volts, or 42 per cent line voltage.

Oscillogram No. 6. Here are shown the full load voltage waves indicating a more pronounced oscillation in the one phase of approximately 165 volts. In contrast with the no load waves the amplitude of each succeeding oscillation is approximately constant.

Oscillogram No. 7. The voltage waves at the transfer point are similar in every respect to those at the full load point, the uniform oscillation in the one phase being about the same.

Oscillogram No. 8. This represents the line voltage waves at the break down point. These waves are of interest in that the oscillation in the one phase previously noted has disappeared. All waves, however, show the ragged appearance characteristic of the abnormally loaded motor.

It may be well at this point to call attention to the operation of oscillographic elements. It sometimes happens that forced oscillations are produced in the element due to some mechanical obstruction in the element case. Experience has shown, however, that in a wave operating at a fixed amplitude, any forced oscillations of a mechanical nature will be of uniform character. A further check on this condition should be made before definite conclusions are drawn.

The voltage waves from the four preceding oscillograms are shown for comparative purposes in the next illustration. They represent in order, the no load, full load, transfer and pull out line voltages. The variation in amplitude of the oscillation in the one phase may be noted at the various loadings.

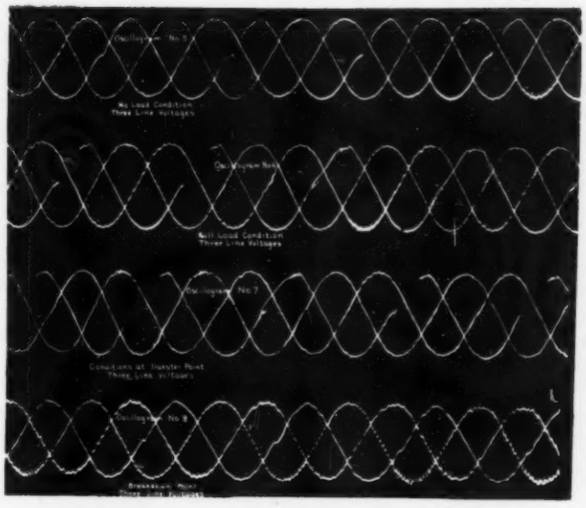
Oscillogram No. 9. The next series of oscillograms represent the relation between the voltage and current in one phase under the different conditions of loading. The same current scale has been maintained throughout and unfortunately the amplitude of the current wave at no load is not sufficient to get the phase displacement accurately.

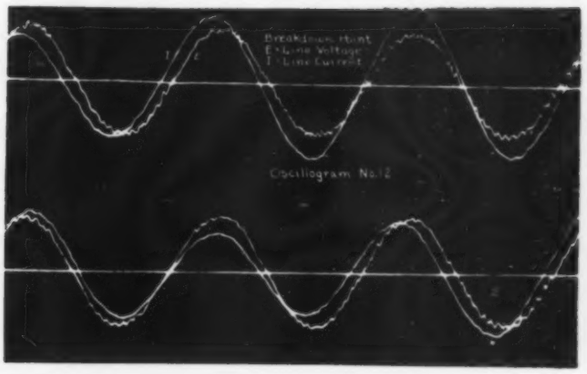
Oscillogram No. 10. The full load current and voltage waves here shown are of uniform value with the current leading the voltage.

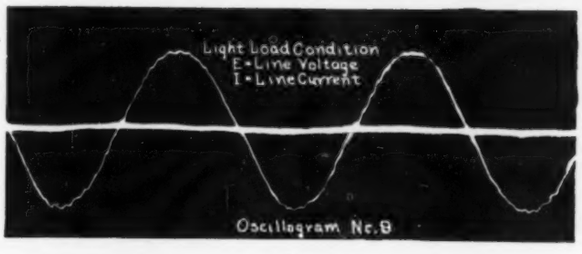
Oscillogram No. 11. At the transfer point we see the current and voltage waves approaching each other from the leading side, coming into phase and slipping out again on the lagging side. A period of approximately 10 cycles represents a change of from 95 per cent leading power factor to 98 per cent lagging power factor. It is evident of course, that the frequency of these surges increase as the motor approaches the pull out point.

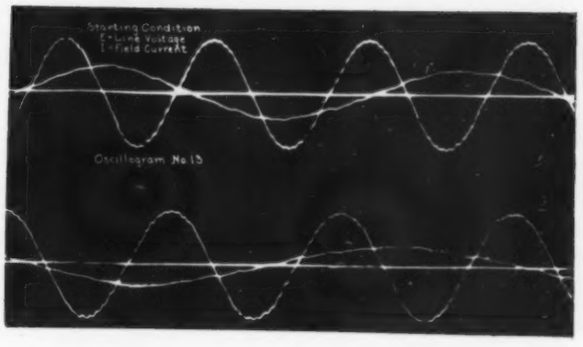
Oscillogram No. 12. At the pull out point here shown, will be noted the same phase shifting from lead to lag and back again as indicated at the transfer point except of course at a higher mechanical frequency. The same current wave attenuation is observed as previously shown in the three current waves. The maximum amplitude of the current wave occurring as the motor approaches induction motor action.

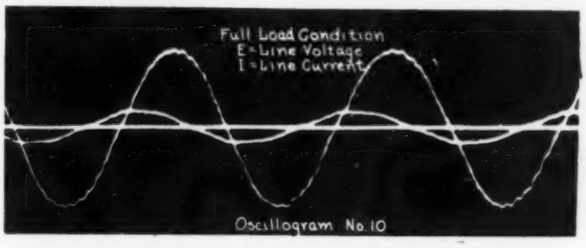
The visual operation of these waves during the test was very interesting. The snapping back and forth

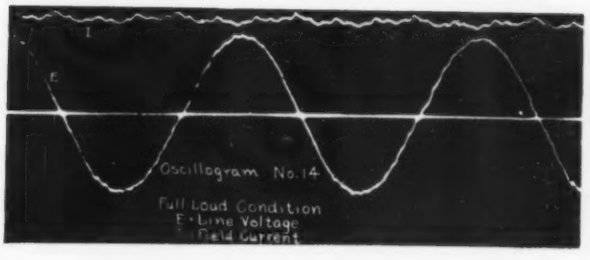


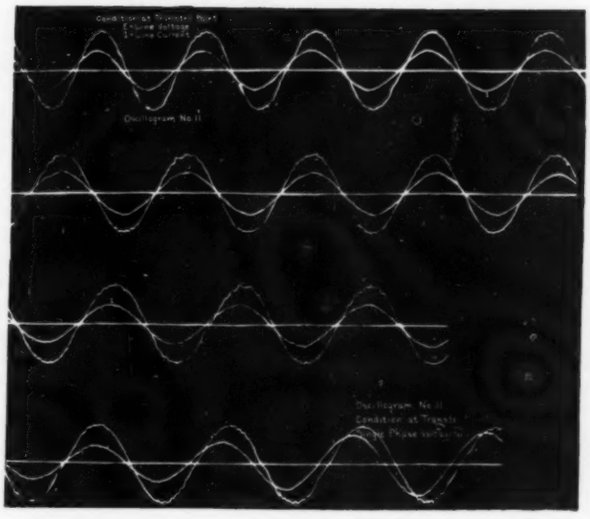

Oscillogram No.12

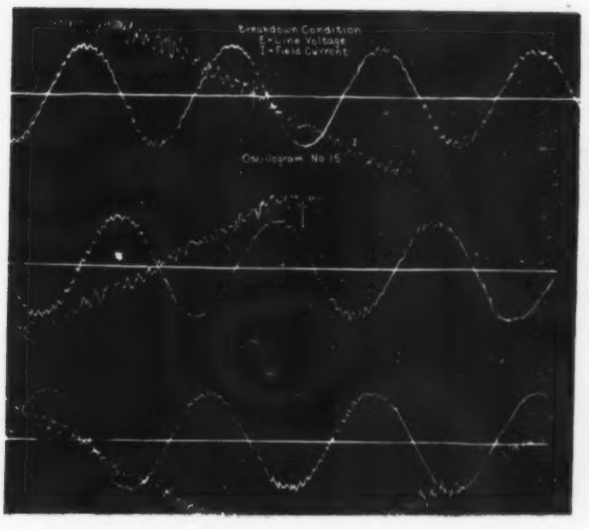

Light Load Condition
E=Line Voltage
I=Line Current
Oscillogram No.8


Starting Condition
E=Line Voltage
I=Field Current
Oscillogram No.13


Full Load Condition
E=Line Voltage
I=Line Current
Oscillogram No.10


Oscillogram No.14
Full Load Condition
E=Line Voltage




Breakdown Condition
E=Line Voltage
I=Field Current
Oscillogram No.15

of the voltage and current waves as they passed from the lead to lag position being very pronounced.

Oscillogram No. 13. The remaining slides show the characteristics of the exciting current during starting, normal load and pull out. The accompanying voltage wave may be used as a time calibration curve. This slide shows the exciting current to be of low and varying frequency as the motor accelerates during the starting period. There is an interval of 14 cycles between the upper and lower sections of the film shown on this slide, during which time the frequency of the exciting current decreases from 24 to 20 cycles per second. As the motor approaches synchronism the frequency of the exciting current approaches zero.

Oscillogram No. 14 shows the characteristic d.c. in the field under full load conditions.

Oscillogram No. 15. This slide shows the change in the exciting current at the transfer point in the motor operation. The frequency of the former d.c. now varies in proportion to the load slip in the motor. Aside from the oscillating character of the wave, it is comparable to the current wave previously shown during the motor acceleration.

In closing, and by way of digression, permit me to call your attention to the importance of oscillographic studies in electrical work. We feel that a careful oscillographic analysis of many manufacturing and operating problems would result, many times, in rapid and effective solutions.

W. A. Layman*: I did not come as a speaker but as an observer, and was much surprised when I saw my name so conspiciously presented on your program. I also came because I felt this was a very important occasion to us. Mr. Farrington has introduced me as an engineer. May I make the frank confession that I began my professional career as an engineer, but now am simply an engineer in business, with engineering responsibilities confined to the executive direction of the engineering operations of our company.

I know of no engineering organization anywhere that more excellently combines the theoretical and practical, than yours. Most engineering associations lean heavily to the theoretical, but you gentlemen, while not neglecting the theoretical, are predominatingly strong on the practical side, and a company such as ours may well take heed of your engineering judgments and recommendations. We are therefore very glad indeed for the intimate point of contact afforded by this meeting.

The motor we present to you tonight is a recent commercial development, as you know, but is not solely the product of recent research effort on our part. On the contrary, it represents the culmination of many, many years of diligent research effort. In the power motor field, our company has specialized almost exclusively on the alternating current type, and it is very natural that our research efforts should have been directed to the improvement of that type. Many years ago we decided the next important step forward would be the production of a thoroughly reliable, simple, commercial form of a.c. motor with unity power factor. So, we went diligently to work to develop it, and the Fynn-Weichsel motor under discussion this evening is our solution of the problem.

In the history of the a.c. system of distribution, there have been three stages of motor development which have been of singular and special importance. The first of these was the invention of the polyphase motor by Nicola Tesla, and its commercial development here in Pittsburgh by the Westinghouse Company. That invention was made just as I was entering the manufacturing industry. I recall vividly with what enthusiasm and pleasure I received a complimentary copy of the volume of Tesla patents applying to this motor, which the Westinghouse Company issued, and I long regarded that book as one of the most highly prized in my technical library. The Tesla motor inventions rounded out the polyphase a.c. system of distribution, and immediately permitted the industry to begin its subsequent marvelous program of expansion. For many years following the introduction of the Tesla polyphase motor, the a.c. motor art practically stood still. There were two limitations of the art which a.c. motor designers fully appreciated One was the absence of a successful commercial single phase motor; the other, the low inherent power factor of all types of a.c. motors.

In the early 90s the engineers of our company went to work with great enthusiasm and diligence, to produce a single phase motor and, in the early part of 1897, we came on the market with what you all know as the Arnold type of single phase motor, the invention of Professor Engelbert Arnold of Karlsruhe, Germany. I believe our development work to have been original, but we had the interesting experience of finding, after the commercial design of the motor was complete, that the principles involved were fully covered by patents of Prof. Arnold, which had never been commercially utilized. We were successful in procuring these patents, and for 10 years or more, were alone in the field of supplying single phase motors above the fractional hp. sizes.

With the development of the single phase motor behind us, we turned to the second problem — power factor correction — in our research work. During the many years intervening, we have approached the solution of this problem from a variety of directions, developing experimentally several designs of motors which have accomplished the desired result. Bearing in mind the satisfactory service standards of the well-known squirrel cage and slip ring motors (giving precedence to commercial requirements above electrical performance), we proceeded, through a process of elimination, until the Fynn-Weichsel motor came to the surface. We believe this motor is one which will give an entirely satisfactory degree of service reliability in every respect, and we look upon it as a successful solution from the operating engineers' point of view of this a.c. motor power factor problem. We do not attempt to say it is the only way the low power factor of a distributing system may be corrected, but we believe it is the first successful way proposed for correcting low power factor at its source. Mr. Hans Weichsel of our staff, who presented the first paper of the evening, is the principal designer of the motor, and he has described it to you fully.

James Farrington*: Undoubtedly this type of motor is going to accomplish one thing which we are striving for, viz.; decreased cost of power and increase in efficiency. If it has reached the perfection the standard motor has, the additional windings ought not to materially increase the usual cost of maintenance.

*President, Wagner Electric Corporation, St. Louis, Mo.

*Elec. Supt., Wheeling Steel Corporation, Steubenville Works, Steubenville, Ohio.

If the maintenance cost can be kept within 10 per cent, additional and allowing 50 per cent increased cost of motor it still shows a saving of about 35 per cent over the standard induction motor.

E. Friedlaender*: We have listened to a very interesting subject tonight. The Wagner Electric Corporation has taken a step in the right direction; in the past, we have always taken it for granted, that bad power factor goes with a.c. motors.

We have learned tonight, that it is possible to build a.c. motors which not alone run at unity power factor but if desirable will correct low power-factor.

I regret, that the steel industry in general will not derive any benefit from this new type of motor as so far it is developed for 60 cycle only. Let us hope that the 25 cycle Fynn-Weichsel will soon be in the market. Our biggest problem is on large drives, where great torque is required for starting and synchronous motors cannot be used. There we have to employ special power-factor correcting apparatus.

In going quickly over Mr. Weichsel's very complete description of his new motor not touching the theoretical features, we have seen that the stator is very much the same as on any ordinary induction motor, with the exception of having two windings in place of one. The motor has slip-rings as well as a commutator and two separate windings. The exciting current is obtained through the commutator from one winding and voltage does not exceed 20 volts. The motor develops a high starting torque with low starting current and starts like any ordinary slip-ring induction motor, but acts like a synchronous motor at synchronous speed. Therefore, the objectionable characteristics in starting a synchronous motor are done away with.

As I see it the motor will operate generally at unity power-factor or if desirable can be made to compensate for the lagging current in the line.

I believe that the greatest benefit from the characteristics of this motor will be derived in the larger capacities, say 1,000 hp. and over.

Where we generate our own power in large stations, power-factor does not play as an important part as in plants which purchase power. There is a question in my mind, whether it would be advisable to install a large number of these motors in smaller capacities to correct power-factor.

The cost of these motors naturally would be considerably higher and the upkeep of the additional windings, commutator and slip-rings probably greater.

Dust and dirt cannot be kept out of these motors in our mills, unless they are made entirely dust proof.

Continuity of service is of first importance in all motor installations in the steel industry. There is also the question of high voltage (6600 volt) on our large a.c. motors.

The Wagner Electric Corporation has paved the way, let us tope other manufacturers will follow in their footsteps.

Orville Buys†: From an operating man's standpoint, I might say when our company first got the motor we were a bunch of skeptics and assumed we would have as much trouble as we used to have with old synchronous machinery, rotary converters, etc. In fact, we expected all kinds of things that did not happen. We have had the motor for two or three months now, and about all the things we thought were bad have proven good points. We thought of half-a-dozen kinds of abuse to give the motor and it stood them all in excellent shape.

J. J. Pannabaker†: Our motors are all small single and three-phase. We use about four or five up to 50 hp. In regard to this particular type of motor, I would like to know whether it will give us trouble when located in dusty places? We are using small squirrel cage motors, 220 volts, and are troubled a good deal with dust, even with squirrel cage motors. The dust seems to cling to the motor. I wondered if we would experience trouble on commutator and collector rings, from that dust. Otherwise, I believe the motor would prove satisfactory.

W. P. Stark‡: Mr. Friedlaender asked about all the questions I had in mind, viz.; what size? and whether we can get it in high voltage?

P. McShane§: I do not think that I have anything to offer. I am very much interested in the motor described this evening. Like Mr. Stark I think Mr. Friedlander has asked the questions that would be of general interest. Time will tell the story. One feature I noticed that would militate against this general application is the inability to reverse motor without mechanical changes. This is a great lacking feature.

O. Needham*: We have had very excellent papers here this evening and a very fine exhibit of oscillograms, which have really covered the subject in so complete a manner that there is not very much left for discussion.

Just in passing it might be interesting to note that in all attempts to change the inherent characteristics of an induction motor it has been necessary to introduce a commutator somewhere in the system.

An induction motor is inherently a constant speed machine. There are, however, a large number of so-called adjustable speed induction motor drives in operation, representing three different systems, namely rotary converter, Scherbius, and frequency converter system. Each of these systems uses commutators.

An induction motor is inherently a lagging power factor machine. Le Blanc and Kapp phase advancers have been used to improve the power factor of induction motors. Each of these systems involves the use of a commutator.

The system of improving induction motor power factor described here tonight is no exception to the above, as it also requires a commutator.

Brent Wiley†: The subject to which the interesting discussion of this evening relates, namely, power factor correction, is one of growing importance.

The Westinghouse Company has given the matter a great deal of study and in analyzing various conditions and requirements has found that various schemes of power factor correction should be considered as no one provision can be made that will give the most

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†Superintendent Equipment Tests, Duquesne Light Company, Pittsburgh, Pa.

†Chief Operator, Vanadium Corporation of America, Bridgeville, Pa.

‡Electrical Engineer, Apollo Steel Company, Apollo, Pa.

§Steel Mill Section, General Engineering Dept., W. E. & M. Co.

*Elec. Engr., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

†Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

practical and efficient result for all cases. Synchronous condensers, synchronous motors, and static condensers have a field, and, undoubtedly, in some cases other corrective measures, such as have been described this evening, are worthy of consideration.

In further reference to the static condenser which is a comparatively recent development, comment has been made that it is expensive and unreliable. The experience of the Westinghouse Company over a period of several years shows that it is practical to design a static condenser with as high a factor of safety as with power transformers, which, as you all know, have established a reputation for reliability. Installations of static condensers which have been on constant service from two to three years have given absolutely no trouble and they are very efficient the losses being not more than ½ per cent.

As regards expense with the average bonus allowed for power factors of 85 per cent or higher by operating companies over the country, which rates in turn are approved by public service commissions, frequent cases have shown that the investment involved for static condensers can be written off by the bonus gained in power bills within periods of from one to three years. The final answer as to expense is not the initial cost of the device but instead the character and continuity of service secured from it and the saving accruing by virtue of improved power factor conditions.

A. B. Holcomb‡: The association is to be congratulated on the very complete presentation of the history, development and operation of the Fynn-Weichsel motor we have had this evening. I wish especially to commend the very interesting oscillographic studies that have been shown. Having done considerable work with the oscillograph I can agree that where a thorough knowledge of internal conditions is desired this is the only certain method.

I am now going to ask the privilege of stepping down in favor of Mr. W. C. Kalb, general manager of our company. I think he may have some remarks which would be interesting.

W. C. Kalb*: This matter is interesting to all brush manufacturers because of the fact that it is an a.c. motor using brushes. The brush business is in some respects like the dry cell business. Several times the dry cell manufacturer has been rated out of the game. He started with the local battery telephone and when the central station power plant was coming into use it was decided the dry cell manufacturer would have to get out of business. About that time the automobile came along and the business took a boom for automobile ignition until the storage battery put a limitation on the demand for dry cells and he was again read out of business. Now we have the radio and the dry cell man is busier than ever. The brush manufacturer at times has looked with a little bit of worry on the growth of a.c. distribution and the elimination of the d.c. power distribution centers, and there has been at times a thought that perhaps in another generation or so we would see the brush business practically wiped out of existence. There was a period when it seemed that nearly every plant we went into would report their d.c. equipment being discontinued and all new equipment squirrel cage. But I believe the trend now is in quite the contrary direction from the brush manufacturer's point of view.

While the developments in a.c. distribution will go on, and with the development of such motors as the Fynn-Weichsel correcting one of the inherent faults of a.c. motors that have been used in the past, the progress of a.c. will receive a new stimulus, I do believe that the brush business will not have to suffer, because most of the methods being used to better the inherent characteristics of the squirrel cage motor are brush using types.

There is one point of a purely technical nature which I would like to have Mr. Weichsel answer: Just what takes place in conjunction with the field of the motor at the transfer point? By means of the oscillograms, we were shown that the field current starts out as a.c. of reducing frequency as the motor begins to speed up. Does that continue to reduce, retaining its alternating character up to the point of zero frequency, or does it at some point become rectified current of oscillating value before it has reached d.c. of practically constant value?

From the standpoint of the brush manufacturer, I wish to express my admiration for the manner in which the problems of current collection and commutation have been taken care of in the design of this motor. I feel that the Wagner Electric Corporation and Mr. Weichsel, the designer, are to be congratulated on having made such a notable step in advancing the application of electric power in the industrial field, a step at once beneficial both to the distributor and the consumer.

H. A. Waddell†: I am practically a stranger to this motor. From what I have seen of it though, I would think it a very desirable motor, even in its present size, to be distributed over the West Penn system. It would help our power factor, although I do not believe we have quite as bad power factor as some other operating companies, due to the fact that our mine operations are run from m.g. sets, which has helped our power factor considerably. But the trend of our new business is going to be a mill load—an induction load. So I think even from the size of this motor distributed to small customers, it would help our power factor.

G. W. Quentin‡ For the past two years the Duquesne Light Company has been making a very careful study of the power factor conditions of its customers.

We have made various tests and compiled some very interesting figures. A special test has been made to determine how the various synchronous motors on our lines are operated, and we have found that the customer seems to be under the impression that the less excitation he puts into his synchronous motor, the more efficiently it is running. Another great handicap to us in our tests is that we have found very few synchronous motors marked with the full excitation amperes. Therefore, it is almost impossible for the customer to know just how much excitation he is allowed to use without overheating, which, of course, would be injurious to his motors. We believe that in the near future the manufacturers will mark the excitation, especially when they realize how important it is to central stations using a power factor rate, and to customers whose power factor needs correction.

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As you know, the cost of equipment, whether furnished by the central station or by the owners of a private plant, is based entirely on the kva. capacity required. In the case of a central station, the costs start at the power house. Poor power factor means larger generators, larger lines connecting our main sub-stations, larger sub-station capacity, increased line capacity to the customer and increased transformer capacity at his sub-station. All these things have grown to such a point that the investment per kva. is increasing so rapidly that very serious consideration must be given to power factor. It is obvious, therefore, that the central station is greatly justified in giving a much lower rate to the customer maintaining unity power factor than to the customer having 75, 50 or any other percentage of power factor.

Last June we put into service a power factor rate, which, to date, has proved very satisfactory, and we have received some very fine results. We are using the reactive component method. This allows for a leading or lagging power factor of 75 per cent, which gives a ratio of the reactive component to the kilowatt hour of 88.2 per cent. For every 10 per cent decrease in this ratio we allow a discount of 1 per cent on the gross bill—that is, if the customer maintains unity power factor he will obtain a discount of 8.82 per cent on the gross bill. This reading is taken monthly and the meters are adjusted to register leading reactive component or lagging reactive component, as the installation in question requires. We have found it necessary to arrange that our meters will not run backwards. We are pleased to state that our general power system is already beginning to show a marked increase and we expect to get far greater results when we have been able to put all our customers on the new power factor rate.

Mr. Friedlaender made the statement that most of you here use 25-cycle current. In looking over the crowd, I would venture to say that there are represented in this room more 60-cycle plants than 25. The Wagner Corporation realizes that the greatest demand for this motor is on 60-cycle development, but I assume they would be pleased to build a 25-cycle motor if the demand justified it.

I would like to add, in closing, that the Duquesne Light Company desires to co-operate with its customers, and we have in our employ competent engineers who are daily making studies of the various power factor conditions. These men are available at any time without charge. We would be pleased to help you improve your conditions with a view to bringing your power costs to a minimum.

J. J. Booth*: The question of 60 cycle vs. 25 cycle is an old chestnut. Many years ago the steel mill engineers adopted, so to speak, 25 cycle as the standard frequency for steel mill work. This frequency was adopted primarily at that time, due to the fact that all the electric power used by the steel mills was generated in their own plants and the question of purchasing power from a central station did not enter into the question.

Then too, at that time, 25 cycles more nearly met the steel mill requirements, due principally to the low speed of the motors, which were more easily adapted to steel mill drives. This being the situation, there were many plants built using 25 cycle frequency, hence many thousands of these 25-cycle motors were installed.

However, with the coming of the large central power stations with cheap power and the improved designs of 60-cycle equipment, 60-cycle is today making great inroads into the steel industry, especially in the new plants, also where cheap purchased power is available.

With this condition existing in the iron and steel industry, it would seem that the company presenting our paper this evening can ill afford to overlook the 25 cycle problem, also check the adaptability of their product to this industry, be it a 60-cycle or a 25-cycle application.

J. H. Albrecht†: What happens with these motors, if you should tie two motors on the same bus, one running at very light load, probably 25 per cent, and the other at 150 per cent; is there any tendency to set up a circulating current?

W. A. Layman: Two or three gentlemen participating in the discussion have referred to the Fynn-Weichsel motor as a leading power factor motor, suggesting the inference of an inherent design limitation in this direction. May I emphasize the fact that the new motor is a unity power factor motor which has the admirable inherent capability of adjustment to a leading power factor as an expedient for correcting the lagging wattless component of an equal capacity of ordinary induction motors upon the distribution system. This feature of over-compensation is at present so urgently desirable that, generally speaking, our recommended form of commercial construction of Fynn-Weichsel motor (except for new installations where no ordinary induction motors are present) will be to supply windings giving strong leading current on light loads, with approximately unity power factor at full and overloads.

I call your attention to a test made by a large public utility company for the purpose of determining what the motor performance would be if installed on a circuit without attempting compensation for lagging currents from other sources.

You will observe the power factor of the motor is almost exactly unity from 25 per cent load up to 150 per cent overload. The power factor of the Fynn-Weichsel motor can be made anything between the curve here shown and the leading power factor curves of Mr. Weichsel's and Prof. Dyche's papers.

I may say quite frankly the motor was not designed primarily for such a group of general users as we have in this room tonight; but I can also emphatically say that no group of engineers or operating men have shown a keener interest in the new motor than has been shown here tonight.

It may interest you to know how we came to develop this motor. At the National Electric Light Association Convention of 1921, a resolution was adopted emphasizing the growing urgency of central station power factor correction, and calling upon the designing engineers of the manufacturing companies to go to work in earnest to solve the power factor problem. The chairman of their Apparatus Committee addressed a letter to all the motor manufacturing companies asking what had been done and what they proposed as a means of providing a.c. motors with higher power factors. Our own organization received this letter, just as all the other motor manufacturers received it.

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Several prominent central station executives who were aware that we had given considerable attention to this problem wrote us strong personal letters urging a diligent application to the problem by our engineers.

This activity strongly stimulated our interest in this power factor problem. As I previously stated, we had worked on it for many, many years, anticipating that the time would come when central station operating engineers would become keenly urgent in their demand for high power factor motors. That we had not made more rapid commercial progress, I may frankly say, was due to the fact that there was not a pronounced incentive for the manufacturers to solve this problem. All our research work had shown clearly that no motor could be produced at the same cost as a squirrel cage or a slip ring motor, and, therefore, until some inducement was offered by those most vitally interested, namely the central stations, it was practically futile for the motor manufacturer to put on the market a motor which he could not sell because of a relatively higher price to the consumer. But, with this emphatic change of sentiment on the part of the National Electric Light Association, and the pressure they began to put on motor manufacturers, we took new heart and went to work aggressively to solve the problem and finish up the work on which we had been engaged for many, many years.

I may frankly say to you that up to the present time our developments have been directed toward a solution of the problem for central stations, and not primarily for the purpose of adapting the motor to the needs of the iron and steel industry.

In the central station industry, 60 cycles is the predominating established frequency of distribution; the small industrial motor is the most frequent producing cause of low power factor; consequently we tackled the problem in our initial development work for a frequency of 60 cycles, and in the predominating range of sizes of industrial motors.

We are face to face with the immediate interesting situation of a widespread and general recognition of the virtues of the new motor and a strong demand from all branches of the industry to respond to their specific needs. We shall respond with the adaptation of the new motor to a wide diversity of applications as rapidly as possible, including motors in the large sizes and for 25 cycles.

Let me say one or two things further from the standpoint of the engineer in business, as I find myself to be, whose job it is as an executive in an organization such as ours, to consider and select between the diversified recommendations of designing engineers. A man like myself is confronted constantly with the great difficulty, as well as the necessity, of keeping up with the technical progress of his own branch of industry, and endeavoring to maintain a sufficiently healthy perspective to judge wisely the direction which the research work of his business should take; and also when several solutions of a research problem are presented to him, to determine which of these solutions should be given commercial precedence. The gentlemen present tonight will agree with me unanimously, I believe, when I express the opinion that the greatest problem in the broad field of education is not the education of the small child; nor is it the education of the high school boy who is ready for the university; but is instead "the problem of keeping the educated man (such as we profess to be) educated."

In the final stages of our development of this unity power factor motor, we laid down the following exacting requirements for our engineers to meet.

(1) It was our judgment that no type of motor would meet the requirements of present day practical service which involved the commutation of alternating currents in any substantial volume.

(2) The consideration of low maintenance expense would be the predominating factor as to whether the motor would be a commercial success.

(3) The general design adopted must be one similar in its essential characteristics with the predominating types of present day motors and with which operating engineers and maintenance men in general were familiar.

(4) While some excess of cost over the prevailing types of motors was inevitable, this excess must not be unreasonable and not preclude the wide introduction of the motor to commercial use.

We concluded the Fynn-Weichsel type of motor to be an answer to all of these requirements in a predominatingly satisfactory way as compared with other forms of construction with which we had made satisfactory progress, and on arriving at this conclusion brought the Fynn-Weichsel motor promptly to the surface, and first announced it to the public through the Apparatus Division of the National Electric Light Association from which the immediate pressure for this commercial development had come.

Before determining upon the Fynn-Weichsel motor for commercial exploitation, we subjected it to the test of the following critical questions:

(1) Would the commutator give satisfactory performance?

Our technical staff answered "Yes," but I personally watched the motors operating under all kinds of ordinary commercial conditions, and in due time fully agreed with their judgment. I have never seen any d.c. motor that gave more satisfactory commutator performance than this new motor.

(2) What would be the cost of maintenance in the field, and could the new motor be repaired by any repair man of ordinary intelligence?

Our engineers pointed out that all the windings were of exactly the same type with which repair shops all over the country and operating maintenance men were thoroughly familiar. Outside practical repair men confirmed this opinion and we concluded there were no problems of this character involved in the proposition.

(3) Would the first costs relative to prevailing types make the new motor a practical commercial proposition?

We found the cost of the new motor ranged from 35 per cent in the small sizes to 10 to 15 per cent in the large sizes above the cost of the well-known slip-ring type. Was this an uncommercial price burden as compared with the old type of motor? After conference with a number of leading central station men, we decided that it was not.

Let me give you the picture put before us by one of the leading men in the National Electric Light Association. He said, that, in his opinion, the average power factor in power stations in the United States did not exceed 75 per cent; that the central station capital account in the United States was five and one-half billion dollars, representing a generating and distribution capacity of approximately 45,000,000 kilo-

watts, giving an average capital cost to central stations of $335 per k.w. installed, including generating stations, substations, and distribution systems to customers' premises; that with a power factor of 75 per cent, one-quarter of this total capital investment, or approximately $83 per k.w. installed was loaded down with wattless current. (Another leading central station man thinks this figure as to idle investment is too high and should be about $45 per kw.) When it is considered that the Fynn-Weichsel motor may be installed to secure unity power factor by employing it in pairs with the old type motor, and that when so installed the additional capital cost will vary from $7.50 to $10.00 per hp. installed, depending upon the size of the motors, it becomes apparent that from the standpoint of invested capital alone, the new motor will free somewhere between $30.00 and $70.00 of central station investment for every hp. capacity of the new motor installed on central station circuits.

In addition, there is the advantage to be gained in a reduction of operating costs for the central station. On one large system having a total capital investment of $44,000,000, the estimate has been made that the low power factor of its average operating load involves an excess energy loss in the system of approximately $350,000 a year. With figures of that kind before us, it seemed to our executive staff there was no question whatever but that the central station industry would receive the new motor with open arms; and that instead of building more power house and distribution capacity for the purpose of carrying more wattless current, they would be willing to pay a part of that $335.00 per k.w. for a higher priced motor, doing this through the medium of some adjustment of their commercial relations to their customers.

As to the isolated power house under private ownership, we felt all the advantages accruing to the central station from the new motor were even more emphatic, and that we would meet with a cordial reception from this source.

As to the Fynn-Weichsel motor being in itself an entire and complete solution of the power factor problem, I frankly and emphatically declare that we make no such professions. There are other devices, such as the synchronous condenser, the static condenser, etc., which have their proper place, and which will very helpfully contribute in relieving the central stations of the tremendous burden of their low power factors.

Going back to my first remark, up to a comparatively recent date we had not thought of this problem as one we were solving for the steel industry, but you are looming up to us as a factor that will have to be taken care of as rapidly as we can come to it.

It cleared up this whole problem to me a little when it was pointed out to me that the wattless leading component in one of the Fynn-Weichsel motors is practically the equivalent of the wattless lagging component of the same size of induction motor. If therefore, as a rough and ready approximation, you assume that so far as wattless current is concerned, an equal capacity of the new and the old type motors will counterbalance and give practically a unity power factor operating condition, the amount of working load the respective motors may be carrying may be disregarded, as the effective working load on each type of motor is at all stages a unity power factor load, for the energy current component is always in phase with the voltage.

H. Weichsel: Referring to Mr. Farrington's question in regard to windings, it can be stated that no new types of windings are used, but the windings employed in this "self-excited synchronous induction motor" are the same type of windings which are commonly used in standard a.c. and d.c. machines. The small d.c. exciting winding is especially simple, as it usually consists of one turn per segment.

Answering Mr. Friedlaender's question regarding 25 cycle motors, no engineering difficulties exist in the design and construction of a self-excited synchronous induction motor for 25 cycle lines. On the contrary, it is easier to design these machines for 25 cycle than for 60 cycle, the reasons being the same as those which govern the design of 25 and 60 cycle rotary converters. It is at present a commercial question which of these machines, the 25 or 60 cycle, should be developed first.

The question of large hp. capacities has been referred to by Mr. Layman. It may be added that there is no engineering reason which could prevent the development of this new self-excited synchronous induction motor for any hp. capacities and speeds desired.

The squirrel-cage motor no doubt is the simplest machine known, and there are certain classes of service where no other machines than the squirrel-cage motor should be used. The self-excited synchronous induction motor is naturally somewhat more complicated than the squirrel-cage motor.

We recommend the use of standard polyphase induction motors together with this new type of machine. This combination will give the desired high power factor in the circuits, as shown in the paper.

The invention of this motor finds an analogy in the invention of the telephone after the telegraph had been in use for many years. The telephone did not supersede the telegraph, but it simply found its own field of usefulness, which admirably dovetailed into that field of the telegraph in which the telegraph was not at its best advantage. It will not drive the standard induction motor off the market, but will partly replace it and partly supplement it.

It is possible to build high voltage machines of this new type, but at present we have not developed a line of these high voltage machines, as the commercial requirements seem to lie mainly in the lower voltages.

One speaker referred to an installation where the air is so contaminated with dirt that open type squirrel-cage motors operating in this plant caused trouble. Naturally we would not recommend the standard open construction of this new type of machine for such dusty places. In places which are so filled with dust that even squirrel cage motors give trouble, it seems to me it would be advisable to entirely enclose the motors and use pipe ventilation. Entirely dust-proof construction is equally feasible for Fynn-Weichsel motors as for squirrel-cage motors.

Another speaker asked if these motors can be used for continuous reversing service. The main advantage of these motors lies in their ability to produce unity or leading power factor when running under normal speed. During starting period, they have the same lagging power factor as an ordinary induction motor. Therefore, in a service which requires continuous starting, stopping, and reversing, a power factor benefit from the new motor could not be expected, and we would not recommend it for this class of service.

It may be added that with a slight modification of

the machine described in the paper it is possible to reverse the machine without shifting the brushes.

Another speaker stated that the improved operating characteristics of this new machine have been obtained by complicating the motor. It is a well-known fact that the operating characteristics of the old type of induction motors cannot be so radically improved without adding something to the machine. It seems to me that the small d.c. commutator which is added in this new motor to the construction of a standard slip-ring motor is so simple that it can hardly be called a complication.

The commutator handles only low voltage direct currents, and during its running period is never required to commutate alternating currents. It is a well established fact that d.c. commutators are very much less apt to give trouble than a.c. commutators, and the reliability of d.c. commutators has been proved by thousands of machines which have been in service for many, many years.

Replying to the question as to how far the d.c. brushes must be shifted when the motor is to be reversed. It is impossible to give a definite figure for this angle of shift, because it depends to a very large extent on the design of the individual machine, but roughly speaking this angle lies between 30 and 40 electrical degrees. In other words, the angle is relatively small, but its exact value, as already stated, depends on the individual design.

Mr. Kalb asked what goes on in this new machine when it is started and goes over into synchronism. In order to answer this question, it is necessary to have a clear physical conception of the operating principles underlying this new type of machine.

At standstill, the rotor winding produces a rotating magnetic field which has a velocity, in respect to the rotor winding and also in respect to a fixed point in space, corresponding to the line frequency and the number of poles of the machine.

For instance, a four-pole machine connected to a 60-cycle circuit would produce a rotating field which at standstill makes 1800 rpm. in respect to the rotor winding and in respect to a fixed point in space. This rotating field cuts the secondary or stator winding and produces therein a voltage which has the same frequency as the line voltage.

When the rotor speeds up, the rotating field produced by the winding on the rotor still keeps on rotating with the same velocity in respect to the rotor winding which it had as the rotor was standing still. The direction of rotation of the rotor, however, is opposite to the direction of rotation of the rotating field in respect to the rotor winding. Therefore, when the rotor begins to rotate, the speed of the rotating field in respect to a fixed point in space will decrease. When the rotor rotates at synchronous speed, then the rotor rotates in respect to a fixed point in space with the same speed as the rotating field rotates in respect to the rotor winding, but both speeds are in opposite direction to each other. The magnetic rotating field must, therefore, be stationery in space. Consequently, the speed of the rotating field in respect to a fixed point in space decreases with increasing rotor speed. From this it follows that the frequency on the brushes of the commutator must decrease with increasing rotor speed.

At standstill, the frequency across the commutator brushes is equal to the line frequency, and at synchronous speed, the frequency across the commutator brushes is zero, i.e., a d.c. voltage appears across these brushes.

That a d.c. voltage appears across the commutator brushes with rotor running at synchronous speed can readily be seen if it is remembered that at synchronous speed the rotating field is stationery in space, and, therefore, acts like the field produced by the poles of a d.c. generator.

Not only the speed of the rotating field in respect to the brushes decreases with increasing rotor speed, but also the speed of the rotating field in respect to the stator or secondary windings decreases in accordance with the same law. Therefore, the induced voltage in the secondary at any time has the same frequency as the voltage appearing across the brushes of the commutator. These brushes are so located in the machine that the voltage across these brushes is always approximately in phase with the voltage induced in the secondary. Therefore, if the commutator winding is connected in series with one of the secondary winding, it follows that a current will flow in this circuit at any speed which is larger than the current which would flow if the secondary is short circuited in itself, and this is the reason why these machines give a large pull-in torque.

One speaker pointed out that in his plant it has been found necessary to underload all motors, and he stated that, for instance, for a 5 hp. load a 10 hp. motor is used. This naturally results in an exceedingly poor power factor in the circuits. Such an installation gives a wonderful opportunity to demonstrate the usefulness of this new type of motor. If the same principle is followed in selecting for this installation the hp. capacity of Fynn-Weichsel motors, a 10 hp. motor would also be used for a 5 hp. load, but under these conditions the machine will run with a heavy leading power factor under normal working conditions, and, therefore, these new motors would counteract the bad effect of the lagging power factor produced by the underloaded induction motors.

Mr. Albrecht asked if it would be possible to operate two of these new type of machines in parallel, so that one is running at no load and the other is running at heavy load.

There is no objection to operating these machines in parallel. If one of the machines is operated with small loads, it takes its current under relatively low leading power factor, and if the other machine is operated, say at full load, it takes its current under approximately 90 per cent leading power factor. The resultant current on the line will be taken under a leading power factor less than 90 per cent. The exact value of this resultant power factor could readily be predetermined by calculation when the characteristics of each of the two machines are known.

Mr. Pannabaker asked if these new machines can be built totally enclosed. There is no engineering reason which makes the total enclosure of these machines impossible, but it must be remembered that any electric motor when built enclosed is considerably larger than a motor of equal hp. capacity built in standard open type. Therefore, the totally enclosed motors must necessarily be much more expensive than motors of the open construction, and this law holds true for the old type of motors as well as for this new type of machine. For most installations, therefore, it will be found more economical not to use totally enclosed motors, but the standard type of machine.

One of the gentlemen present has asked me how the efficiency of the Fynn-Weichsel motor compares with that of slip ring and squirrel cage motors. I am glad to answer this question very fully as follows:

First. Under all operating conditions the Fynn-Weichsel motor is designed to give equivalent efficiency to the slip ring type of motor.

Second. The efficiency of the Fynn-Weichsel motor, as of the slip ring motor, may be improved by more liberal use of materials, if this is considered economically desirable.

Third. In the design of the Fynn-Weichsel motor, three ends are sought:

(a) An improvement of line regulation.

(b) A contribution, to the system, of leading wattless current, to compensate for an excess of lagging wattless current in the system.

(c) An operating efficiency as high as may be attained, consistent with the other two objects sought.

Therefore, in our present design of the Fynn-Weichsel motor which we are offering commercially, we have not sought to attain the maximum efficiency possible, but have rather designed for all three advantages.

The efficiency of the Fynn-Weichsel motor with a given set of windings varies 3 to 4 per cent according to the setting of the brushes. Standard machines have their brushes located for best all-around operating conditions, and brush settings should not be disturbed.

Fourth. A squirrel cage motor as normally designed for general purpose work can readily be given an efficiency of 2 to 4 per cent better than the commercial forms of slip ring and Fynn-Weichsel motors. There are, however, a great many commercial instances where high resistance squirrel cage rotors are necessary for the purpose of attaining increased starting torque, and in such instances a substantial part or all of the efficiency advantage over the slip ring and Fynn-Weichsel types is sacrificed to secure this torque. The usual commercial types of Fynn-Weichsel and slip ring motors will give all the torque required for practically any ordinary commercial installation that may arise, and with a starting current efficiency that cannot be attained in any squirrel cage motor of either low or high resistance rotor.

Fifth. It is important to remember that the present commercial forms of Fynn-Weichsel motor have been designed to be used in pairs with the normal type of squirrel cage motor, and, therefore, the overall efficiency of these pairs may be regarded as having only half the difference of efficiency indicated as between a Fynn-Weichsel motor and a low resistance squirrel cage motor operating separately.

It is also well to remember that commercial practice is more and more turning to the elimination of the squirrel cage motor, and the requirement of the slip ring type or its equivalent for the purpose of reducing starting currents. It is more or less general European practice to require slip ring motors for 5 hp. and upward and we may expect a steady turn of American policy in the same direction. Some central stations are already imposing very rigid requirements on starting currents which cannot be met by the squirrel cage motors. Therefore, efficiency comparisons may less and less be made between the Fynn-Weichsel and the squirrel cage and more and more as between the Fynn-Weichsel and slip ring motors, where, as above stated, practical equality will exist.

Sixth. One of the advantages for the Fynn-Weichsel motor arising from its correction of power factor at the source is that a considerable energy gain is made in the local plant wiring system, and it is entirely probable that any efficiency loss in Fynn-Weichsel motors operating in pairs with squirrel cage motors, as compared with complete installation of squirrel cage motors, will be fully offset in the plant efficiency as a whole, including distribution losses with motor losses.

Seventh. In this discussion of efficiency between types of motors, it should be taken into account that actual brake efficiency tests are difficult to make, in fact so difficult that the common practice in factory work is to rely largely on the measurement of the segregated losses arising in the motor, from which calculated efficiencies are determined. Prony brake tests when made are generally used for comparative purposes only and are always found to be subject to wide variations with individual observers in the tests, this making their employment less desirable than the indirect method here referred to.

There have now been made in various universities and by central station laboratories a very considerable number of efficiency tests on the Fynn-Weichsel motor and these average up very closely to the published efficiencies which our company has issued.

Power Generation in Modern Steel Works

By G. R. McDERMOTT*

THE modern steel plant consists of by-product coke ovens, blast furnaces, open hearth furnaces for steel making, rolling mills, and power generating units.

The by-product coke ovens are one of the four important links in the chain of primary units in the steel works. Eighteen to 20 per cent of the calorific value of the coal charged in a coke oven appears as by-products consisting of liquid and gaseous products which are available for steel making for reheating furnaces, ammonium sulphate, the lighter oils, benzol and toluol, etc. Frequently the surplus coke oven gas is interconnected with municipal gas works. About 70 per cent of the heat in the coal is represented in the coke produced.

The coke ovens provide the fuel in the form of coke for the blast furnaces. In the steel plant these furnaces are the greatest consumer of fuel; however, they are also at the same time the greatest producers of a valuable by-product, blast furnace gas, containing about 50 per cent of the calorific value of the coke charged into the furnace. The coke rate of the fur-

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nace, i. e., pounds of coke per ton of pig iron produced, depends on the efficiency of the furnace; as the coke rate increases there is an increase in the calorific value of the blast furnace gas leaving the furnace.

The modern blast furnace produces on an average of 550 tons of pig iron per day, although there are blast furnaces in operation at the South Chicago plant of the Illinois Steel Company which have averaed 685 tons per day for a month without scrap charge.

The quantity of gas produced from a 550-ton furnace at a coke rate of 2,000 pounds will amount to approximately 138,000 cubic feet per ton of iron or at the rate of 76,000,000 cubic feet per day, no allowance being made for reduction of gas production during the casting period. The above average gas is distributed approximately as follows:

	Million cu. ft. per day	Million B.t.u. per hour	Percentage
Required for the blast furnace stoves	26.6	103	35
Consumed by gas blowing engines	7.6	29	10
Losses	3.04	11.8	4
Surplus available for steam and power generation	38.76	150.7	51
Total	76.00	294.5	100

A steel plant with six blast furnaces installed and in operation will therefore produce gas for the generation of power at a rate of 1.6 million cubic feet per hour while all furnaces are active, or at a rate of 1.32 million cubic feet per hour while one of the furnaces is casting.

The gas as it is delivered from the blast furnace contains dust which should be removed before it is used in the stoves, boilers and gas engines. This is accomplished in a number of plants by washing with water. Firstly by tower washers known as primary washers and secondly by Theisen washers or secondary washers.

The primary washed gas is used as fuel for the blast furnace stoves and steam boilers, while the secondary washed gas is used as fuel for the gas blowing engines which supply the air blast for the furnace itself and also for gas electric power engines. Starting with the cleaned gas, the alternatives are steam raising, using steam in engines and turbines, or using the gas in internal combustion engines. The over all efficiency from fuel to power generated is in favor of the gas engine.

As has been shown above, about 10 per cent of the gas output is used for blowing the furnace and approximately 51 per cent is available for production of electric power. The gas engine predominates in the plants of the Illinois Steel Company for the blowing of blast furnaces and the production of electric power. The engines are of the four-cycle twin tandem type and in the case of the electric units the drive is direct connected to 3-phase, 25-cycle, 2200-volt generators. The thermal efficiency of these units will average 24 per cent for a month's period for power delivered at the switchboard. The available gas from the hypothetical blast furnace plant of six furnaces will permit the generation of electric power with internal combustion engines to the extent of 50,000 to 60,000 kwh., although the steel mill load for this hypothetical plant will probably only average in the neighborhood of 25,000 kwh.

The open hearth department is the next link in the chain of units which consume large quantities of fuel. When coke ovens are installed in the steel works, the by-product gas in combination with the by-product tar is used as fuel for the open hearth and reheating furnaces of the rolling mills.

In the case of the open hearth furnaces, the thermal efficiency, based on the ratio of net heat used by converting the metal charged in the furnace to steel to the total heat in fuel supplied, is comparatively low. The efficiency in a well designed furnace amounts to about 17 per cent. Of the losses, 55 per cent is represented in the sensible heat of the waste gases which are discharged from the furnace stack. By the installation of a waste heat boiler and economizer about 45 or 50 per cent of the stack losses may be recovered in the form of steam.

The pig iron production from six blast furnaces would produce one and three-quarter million tons of steel ingots per annum, assuming that 65 per cent of the material charged into the open hearth furnaces is hot metal from the blast furnaces. The above ingot production would require an installation of 26 100-ton open hearth furnaces. The temperature of the waste gases at the stack of the furnace vary from 1100 to 1300 deg. F. The heat from these gases, when used for the production of steam, is absorbed largely by convection, which necessitates the passage of the gases over the heating surface of the boiler and economizer at or near the critical velocity of the gases. The rate of heat transfer per square foot of heating surface increases with an increase of the ratio of weight of waste gases per hour to square foot of gas passage area. It also increases inversely as the diameter of the tube. At the Illinois Steel Company, South Chicago plant, we have installed fire tube waste heat boilers and economizers of our own design. Induced draft fans are necessary to provide the requirements of the furnace and draft loss through the waste heat boiler which is comparatively high on account of the required high gas velocity through the boiler. These fans may be either motor or steam turbine driven, depending on feed water temperature conditions.

The waste heat steam generated from the 26 furnaces mentioned above would amount to approximately 13,000 net boiler horsepower hours from and at 212 deg. F.

While on the subject of steam generation from waste gas, it is fitting that your attention be drawn to the sensible heat energy contained in the exhaust gases of a modern gas engine. This energy is probably equivalent to between 35 and 40 per cent of that developed by combustion in the cylinder. The temperature of the waste gases near the exhaust valve is about 950 deg. F., and by the installation of a fire tube type of boiler designed along the lines of a waste heat boiler for open hearth furnaces it is possible to generate 2.25 pounds of steam at 250 pounds pressure per kw. generated by the gas engine. The cooling water from the gas engine may be used as feed water for such a boiler. The steam generated in this manner from a large gas engine installation becomes available for the generation of power by a high pressure turbo-generator. Based on a 25,000-kw. load, the waste heat steam from gas engine exhaust would generate 3750 kw. by means of a turbo generator having a water rate of 15 pounds per kw. The gross

thermal efficiency from fuel to switchboard has thereby been increased from 24 to 27 per cent.

The remaining important link of the steel plant is the rolling mills. The main rolls and auxiliary drives of the modern plant are motor driven. The kind of motor installed is determined by the type of mill. The reversing mill requires a d.c. motor, the current for such is supplied through a medium of a motor-generator set and flywheel. The continuous mill is driven by either a direct connected low speed a.c. and flywheel or high speed motor with gear reduction set and flywheel. The load conditions imposed by the rolling mills are at times severe, which require the installation of heavy flywheels in connection with the motors driving the main rolls. These flywheels to a large extent assist in absorbing the local peak loads which otherwise might cause abnormal power disturbances and requirements at the main generating station. A steel plant of the ingot producing capacity as outlined would require in the neighborhood of 25,000 kw., average, with momentary peaks amounting to 35,000.

Conclusion.

As a result of the foregoing brief outline, it is possible with a well designed steel works concentrating coke ovens, blast furnaces, steel making and rolling mill departments, that all surplus blast furnace and coke oven gas, the generation of steam by the utilization of sensible heat in the waste gases discharged from the stacks of open hearth and reheating furnaces and gas engine exhaust, rolling mills electrically driven would result in very little coal being consumed directly under the boilers for power generation. The bulk of the coal would be consumed at the by-product coke ovens for the making of coke for the blast furnaces. The steam generated by the utilization of the sensible heat energy in stack gases and gas engine exhaust would be available for miscellaneous purposes and for electric power generation by turbo generators installed to assist the gas driven generators and thus form an elastic combination for absorbing the fluctuating demands from the rolling mill motors. As has been indicated above, there will be a surplus of blast furnace gas over and above that required for electric power generation. Such surplus may be used in combination with producer gas generated from waste coke for heating of coke oven, also as gas for melting in the open hearth furnaces and reheating furnaces, fuel, etc.

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*Steel Mill Electrical Machinery and the Insulation Problem**

By C. E. SKINNER†

FOR our present purpose, we may say that the development of the insulation art began with the introduction of dielectric or breakdown testing. This method of determining insulation values was little known prior to 1890. With the exception of series arc generators, the voltage of machines in use prior to that time was usually 110 or 220 volts, with a few street railway systems at 500 volts, with the beginnings of the development of the a.c. system at 1100 and in a few cases, 2200 volts. The recognized methods of testing insulation in the late '80's and the early '90's were by ringing out with a magneto or by measuring the insulation resistance. With the introduction of 500-volt railway motors and the 1100 and 2200 volt constant potential a.c. systems, insulation troubles became so numerous that new methods for determining insulation values were absolutely necessary. As there was very little written in regard to the general subject during the development period, your speaker must depend to a considerable extent for his historical sketch on his actual contact with the early development of the dielectric testing and its relation to other kinds of tests, and to the design of insulation for use in dynamo electric machinery. I do not know where the scheme of applying a.c. high voltage to the testing of insulation originated. In the early part of 1891, I was asked by our superintendent, Mr. Albert Schmid, to undertake work of this kind. Through the help and counsel of Mr. C. F. Scott, then chief electrician of the company, testing apparatus for this purpose was gotten together. The early testing equipment was indeed very crude, and consisted of a number of voltmeter transformers with their low tension windings connected in parallel, and their high tension windings connected in series. One of these transformers was especially wound with loops so that by bringing out leads from the connection between the transformers and from the loops on this special transformer to dials, potentials from 100 to 6,000 could be obtained. With this outfit, a very large number of tests were made on the available insulating materials, and the testing of finished windings, particularly armature windings, was systematically followed out. The ancient records still reposing in my desk show that in the testing of railway motor armatures, for example, at 750 volts a.c., 25 to 33 per cent of the armatures tested broke down, when these same armatures would show satisfactory results when tested by magneto or by the measuring of the insulation resistance.

As this breakdown test resulted in a burned spot at a definite location which was easy to find, the reason for these breakdowns became apparent, and in a very short time changes in the methods of applying the insulation resulted in improvements such that there was a very great decrease in the percentage of breakdowns, even with considerably increased dielectric test. Incidentally, it may be of interest to know that one of the major difficulties with the original testing apparatus was the breakdown of the apparatus itself, due to the fact that the transformers used were

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not insulated for the higher voltages which the equipment was capable of generating. This difficulty was overcome by winding a special transformer, which we called an insulating transformer, each secondary coil being very highly insulated, and supplying current to the primary of a testing transformer in place of the parallel connection previously used. By insulating the cores, a reasonable satisfactory equipment could be maintained.

With the beginning of high voltage constant potential transmission at 11,000 volts, requirements for higher and higher voltage testing became necessary. The initial equipment for this purpose was made up in very much the same manner as the original outfit, using 1100 and 2200-volt transformers in series, in this case each individual transformer being immersed in an open tank of oil. By these means we succeeded in producing a 40,000-volt testing set, which at the time was considered quite an accomplishment. With this outfit, the dielectric tests were made on various insulating materials, transformer models, and oil, which were used in connection with our first transmission plant, that known as the Pomona transmission. These researches covered many months of detail testing. It was at about this time that Nikola Tesla startled the electrical engineering world by his experiments with high frequency currents with voltages far beyond that of our testing outfit, and, not to be outdone, we built an equipment of the Tesla type, which when used with our 40,000-volt equipment, would reproduce most of the Tesla experiments, giving striking distances of 15 to 20 inches. In addition, a spectacular development of our own ensued, which was brought about by the application of 20,000 to 40,000 volts at ordinary frequency to a large plate of insulating material, such as plate glass, the back of the plate being covered by tin foil, and metal letters placed on the front, and the potential applied between them. This formed the basis of an exhibit installed at the World's Columbian Exposition in Chicago, and attracted very considerable attention on account of the spectacular production of miniature lightning and the accompanying noise which could be heard for a considerable distance. In fact, this exhibit so interfered with telephone communication at the general switchboard a few hundred feet away in the same building, that the authorities finally limited our exhibitions to two or three comparatively short periods during the day.

Prior to the Chicago exhibit installation, Mr. Joseph Jefferson, the actor, happened to be playing in Pittsburgh, and became the guest of Mr. George Westinghouse, who took him on a tour of inspection of the works, then located at Garrison Alley and Fayette Street. It was at this time I had the honor of playing on the high tension equipment, to Mr. Westinghouse and Mr. Jefferson as an audience, and I recall the remark of Mr. Jefferson after various spectacular demonstrations had been made, in which he assumed the role of Rip Van Winkle, and remarked that the "ozone generated reminded him of his sleep in the mountains."

There was much more to be done, however, than to stage spectacular exhibits, although such exhibits became almost a part of my daily work, as my testing equipment became more or less a Mecca for all our officials to show off to various visitors who came to the factory. With this higher voltage equipment, we entered into a new phase of the testing, and development in connection with high tension transmission. One of the most important parts of the work at this time was the research carried on in the development of insulating oil for transformers. In this research, every known oil, vegetable and mineral, that seemed to have any chance of being worth while was thoroughly tested, and mineral oils from the heaviest engine oil to benzine were studied. This early work was the beginning for the Westinghouse Company of the use of oil in amounts which now run to millions of gallons per year. The story of the development of transformer oil alone, while perhaps much more interesting to your speaker than to his audience, would, if written up in detail, make a good-sized book.

In 1890, the Westinghouse Company brought out its first single reduction, drum wound, slotted armature railway motor, the electrical design of this machine being due to Mr. B. G. Lamme, then a young engineer just recently out of college, and the mechanical design being due largely to Mr. Albert Schmid, our superintendent. This machine was a radical departure in its fundamental points from any electrical motor then on the market. The fundamentals of this design were: First, a circular magnetic field with inwardly projecting poles, this field acting as a protection to the field coils; second, an armature with open slots and drum type of winding; and third, formed coils individually insulated before application; and it is interesting to note that this design in all its essentials is the design almost universally used in d.c. railway motors today. As has already been stated, the application of the dielectric test to these new armatures resulted in a very large percentage of breakdowns, and as a matter of fact, the insulation on the original coils was pitifully inadequate, consisting as it did of "U" shaped cells not closed, covered with a layer of friction tape. The dielectric test at once revealed the weakness of this insulation and it was very quickly remedied by the use of heavier insulation, the cells lapped and sealed, and thoroughly varnished, a type of insulation in very large use today.

Difficulties with the varnish used on these coils led to the development of insulating varnishes which up to that time were unknown as such. As is well known, the insulating varnish business has become a very specialized business, and at the present time a very large number of companies manufacture varnishes of this class as their exclusive business or a considerable portion thereof. Again, like the transformer oil, the story of the development of insulating varnishes, with the innumerable difficulties encountered, would make a story of itself.

Insulating Materials, Their Characteristics and Limitations.

The number of materials which are or may be used for insulating purposes is extremely large. They include the whole range of solids, liquids and gases. Among the solids, nearly every form is used except the metals, and even here we make use of some of their compounds, such as oxides. Among the liquids, certain hydro-carbons, such as mineral oils, are very largely used, and air might be called the universal insulating material, supplementing as it does all others in all our constructions.

The physical characteristics of materials are as variable as the materials themselves, and it must be confessed that practically no known insulating material has what we might call ideal physical charac-

teristics. In fact, they are among the poorest from the physical standpoint in the list of materials used for construction work. Their contrast to the other materials of construction used in dynamo electric machinery and other apparatus is very striking indeed. The magnetic circuit is always made of iron, and the structural parts are usually of iron and steel, while copper is almost exclusively used as the conducting material. Contrasted to these, we have for insulation, paper, mica, cloth, varnish, porcelain and numberless compounds, none of which even approach in satisfactory mechanical characteristics the metallic parts of the machine composing the conducting, magnetic and structural features. In fact, the more familiar we become with dynamo electric machinery and apparatus, the more we sometimes wonder that the stability of such machines is as satisfactory as it is when one is familiar with the insulating materials which of necessity must be a component part of the structure.

Many years ago, when I thought I knew more about the insulation art than I do at present, I essayed to write a book on the subject and looked about for an example of the ideal insulating material. Naturally I did not find any such ideal, even for specific applications. One can readily specify characteristics which would be satisfactory, but he might find it impossible to get his specifications filled. For example, the most satisfactory and, in fact, the almost universal material for use between commutator bars is mica. To be satisfactory, this material must be very carefully selected and very carefully processed with constant attention to keeping the quality right. It must not be too hard. It must be properly split, and the bond must not leave conducting material from the sparking at the brushes. How much more satisfactory it would be if a material of the same physical characteristics as copper were available, except that it be an insulator.

Oil is used almost universally for the insulation and cooling of transformers, yet oil has characteristics which we would very gladly see changed, particularly inflammability and the consequent potential danger of fires where oil is used. Thanks to 30 years and more of intensive engineering and development work, these undesirable characteristics have been so hedged about by modern constructions that fires are very rare indeed, and when they do occur, provision made in advance can usually take care of them with no damage except to the individual piece of apparatus. Many of us can remember disastrous fires before the modern type of transformer was developed. A fireproof or non-burnable insulating liquid, stable at all ordinary operating temperatures and with no affinity for water, is indeed desirable, but up to date none has been found with the satisfactory characteristics of properly processed mineral oils. All those which have been tried have some defect. One may give off poisonous fumes, another may have too low a boiling point, and still another may have uncertain insulating qualities or may attack the other materials of construction. I still have hope that a superior non-inflammable insulating liquid will be found, but I have no idea where to look for it at present.

Porcelain is the almost universally used material for insulators on transmission lines. Any of us could very readily write a specification for a material which would have the insulating characteristics of porcelain and which would have far better mechanical characteristics. Unfortunately, again the ideal material for this purpose has not as yet been discovered. We insulate our transformer windings, armature and field windings, and our cables, with cotton thread, cotton tape, paper, mica, varnishes, impregnated compounds, rubber, gutta percha, etc. Each application has its best available material or combinations and each has the weaknesses of even these best materials to contend with. The best we can do is to so design our structures as to overcome, to the greatest possible extent, the known weaknesses in all these materials, and the fact that many machines have operated for 20 years or more with entire satisfaction indicates that in spite of these inherent weaknesses, the insulation engineer has been able to design structures which may be considered quite satisfactory.

Many classifications of insulating materials have been suggested, and such classifications usually depend on the angle from which the classification is approached. Some of these classifications are:

(a) By physical state—as solids, liquids and gases.

(b) By composition—as organic and inorganic materials with their various subdivisions.

(c) By form—as sheet or laminated, tapes, cloths, papers, molded forms, etc.

(d) By reference to temperature limitations.

The latter classification, that is, by reference to temperature limitation, is the one which has been adopted by the American Institute of Electrical Engineers in connection with the rating of electrical machinery, and is perhaps the most useful for the consideration of this paper. An enormous amount of work has been done to determine the limiting temperatures which various insulations will stand without serious deterioration. Please note that I used the word "serious" in connection with deterioration. There are very few insulating materials which do not undergo a certain amount of change even when subjected to normal atmospheric temperatures and humidities, and the amount of change with temperature and its effect on the characteristics of the material varies enormously with different materials. The temperature limits which have been set by the Institute are based on both experimental tests and long experience with the various materials in common use for insulating purposes.

The Institute classification provides for four general grades or classifications as follows:

Class O—Cotton, silk, paper and similar materials when neither impregnated nor immersed in oil. Temperature limit 95 deg. C.

Class A—Cotton, silk, paper and similar materials when so treated or impregnated as to increase the thermal limit, or when permanently immersed in oil; also enameled wire. Temperature limit 105 deg. C.

Class B—Mica, asbestos and other materials capable of resisting high temperatures, in which any Class A material or binder is used for structural purposes only, and may be destroyed without impairing the insulation or mechanical qualities of the insulation. (The word "impair" is used in the sense of causing any change which would disqualify the insulation for continuous service.) Temperature limit 125 deg. C.

Class C—Materials capable of resisting higher temperatures than Class B, such as pure mica, porcelain, quartz, etc. No limit given.

These classifications are at best an estimate based on experiment and on service as to what temperatures the various materials will stand continuously without deteriorating to such an extent as to cause the destruction of the material or the breakdown of the apparatus on which it is used. Many attempts have been made to establish a satisfactory measure of the deterioration of insulating material as caused by temperature. To date, I know of no measure or any set of measures which are capable of giving numerical values for the deterioration of insulating material when subjected to these or other temperatures. If we assume that the mechanical strength is a measure, and that a reduction of mechanical strength to, say, 50 per cent or to 10 per cent of the original value be taken as the point at which the material has deteriorated, then we must make tests on material in a shape very different from that in which it would ordinarily be applied as electrical insulation, and we would condemn it when it has perhaps just reached its maximum value as an insulator. If we assume that the measure is that of insulation resistance, we will find that the insulation resistance in most cases will increase in value to a point where the material is almost utterly destroyed, so far as physical characteristics are concerned. If we assume that dielectric strength is the proper measure, we will encounter the same difficulties as with insulation resistance. Furthermore, it is at once evident that a test which is applicable to solid insulators is not applicable to liquid insultors, and that materials which are capable of withstanding quite high temperatures, such as mica, but which are usually held together by an organic bonding material, will require a totally different measure from a fabric which is impregnated with varnish, for example. These examples indicate some of the difficulties facing the investigator in attempting to evaluate the characteristics of insulating materials.

With the above facts in mind, you can appreciate some of the embarrassment which the American delegations to the International Electrotechnical Commission have experienced when advocating these classifications for international agreement, when the request is made by our European friends for the exact laboratory proofs that these classifications are correct. We can hardly argue that Class A insulation is capable of withstanding 105 deg., and that we should not use it for 106 deg. The facts are that most of the available materials will stand temperatures considerably beyond those given by the Institute classification, at least for short periods, without serious deterioration. There has been much speculation and argument as to whether such materials, when subjected to temperatures below the limits set, for a major part of the time, are capable of withstanding without serious deterioration temperatures considerably in excess of the classifications limits for an indefinite number of shorter periods. In other words, this covers the very much discussed question of overloads and overload guarantees on machines. It is probable that a time temperature integration would give the proper measure of this effect—if only we had a satisfactory measuring stick. From long experience, and with the accumulated results of such tests as have been made, it is now quite certain that the Institute classification on the basis of temperature is reasonably conservative, if we assume that the life of any machine should have a normal limit of, say, 15 or 20 years.

As is well known, the temperature rating of electrical machinery, both national and international, is based on the temperature which the insulation will stand, and this phase of the subject is therefore one of very great importance. It is of peculiar importance to steel mill electrical engineers because of the extreme conditions of service which steel mill machinery must meet to be satisfactory. It is indeed unfortunate that we do not have more exact information, but this is due not to any lack of attention on the subject by any engineers, research men, manufacturers of insulation, and users, but to the extreme difficulty, if not impossibility, of devising ways and means for securing this desired exact information. It is certain, however, that every available insulating material has distinct limitations beyond which one must not go or the material is destroyed. These limitations are almost as variable as the materials themselves, and they concern not only the temperature limitations but the limitations due to moisture, to mechanical stresses, and to many other causes. After long experience and by taking advantage of every possible condition to conserve the material, many of these limitations have been at least partially removed in modern electrical machinery. The limitation due to absorption of moisture has been very greatly removed by the application of varnish and varnishing methods, and by proper mechanical support. The physical weaknesses of insulating materials have been recognized in designs which subject them to great mechanical stresses, and the resulting structures are usually very satisfactory. Varnishing and impregnating, in addition to increasing the resistance to moisture, also have the merit of increasing the resistance of insulating materials to the effect in temperature. For the higher temperature applications, structures are often so designed that the bonding material, for example, necessary in applying mica, may be entirely destroyed without seriously deteriorating the structure as a whole. In fact, the modern electrical machine is one of the very reliable devices, due not to the inherent desirable charactristics of the insulating material used, but to a knowledge of its limitations, which has led to the design of structures in which these limitations are taken care of.

Insulation Testing.

I have already referred to the beginnings of insulation testing by the dielectric or breakdown method. This method has become, both nationally and internationally, the adopted method for evaluating the integrity of the insulation of electrical machinery. I have stated that at the beginning of our own work railway motors for use on 500 volt grounded circuits were tested at 750 volts, with a very large percentage of breakdowns when the tests were started. The evolution of the standard test today has been brought about through the establishment of tests of this kind, primarily by the manufacturers, for their own information and protection. Later these became incorporated in specifications for the purchasing of machinery. At a still later date the standards committee of the American Institute of Electrical Engineers adopted a series of insulation tests based on the practice of the day. The present almost universal standard is for a breakdown test of twice normal rated voltage of the apparatus plus 1000 volts. There are certain exceptions to this general rule, but these are

relatively few. After 15 or 20 years' use of this test, which of course is based on practice rather than on theory and laboratory proof, it appears to be entirely satisfactory for all ordinary purposes. A lower test probably would not search out all the fatal weaknesses which might exist in the insulation, and a higher test often makes necessary the use of more insulation than is considered desirable, on account of other difficulties which may arise with increased insulation. As is well known, insulating material is a good heat insulator as well as a good electrical insulator, and consequently the more insulation used the greater the difference of temperature between the windings and the core or cooling parts of the machine. Also, in certain constructions, such as the fields of turbo alternators, the mechanical structure is of very great importance, and practically no movement of parts is allowable due to the fact that such shifting of position may throw the rotor out of balance. Most insulating material is subject to expansion and shrinkage due to the change of condition brought about through moisture, and particularly temperature. Consequently, rotors for high speed machinery are usually designed with as small an amount of insulation as possible consistent with the necessary dielectric strength, and the material used is processed to the extreme limit possible to reduce shrinkage. I recall a particular case where the purchasing specifications for a turbo alternator contained a requirement for a dielectric test on the rotor, which made satisfactory mechanical construction of the rotor almost impossible, both on account of the increased heat insulation and on account of the danger of shrinkage of the structure which might result in fatal unbalancing.

The application of insulation to electrical machinery is a series of compromises between conflicting requirements and conditions. This, together with dealing with a class of materials which cover an almost infinite variation in physical characteristics, makes the insulation art perhaps one of the most difficult to deal with in all electrical design. If I did not know that this group is entirely familiar with many installations working under extremely difficult conditions, with entire satisfaction to the user, I would hardly dare deal so frankly with the characteristics and limitations of insulating materials in general. The fact that these installations are successful under extreme conditions is ample indication that much has been done to so utilize available materials as to make the best of them even with their limitations. I often feel that insulation and people are very much alike. In dealing with people we must take into account their characteristics and limitations and utilize the things which they are capable of doing to the best advantage, and so plan that their traits which limit them obtrude as little as possible. In the same way the insulation engineer must know the weaknesses of the materials with which he deals and so apply them as to shield their weaknesses to the fullest possible extent.

Manufacturing Processes.

The manufacture of insulating material and the application of insulation to electrical machinery takes on as varied phases as the insulation itself in all its varieties. I assume that you will be interested mainly in those manufacturing processes which have to do with the application of insulation to electrical machinery and not so much in the manufacture of the insulation itself. Some of the latter processes are, however, very interesting, such as the manufacture of porcelain, the manufacture of papers, laminated sheet material, tapes, varnishes, transformer oil, and many other similar materials. Each one of these is more or less a business in itself, and many improvements have been made during the time in which your speaker has been in contact with this work. In fact, the manufacture of insulation as a business has largely grown up during the time in which I have had a specific interest in this subject. In some cases years of experimental work were required before reasonably satisfactory material was put on the market, and like every other phase of manufacture in any line, constant attention is required in order to keep abreast with the necessary improvements which must be brought about to meet competition and to meet the ever growing requirements for higher voltages, better service, and new applications.

The manufacturing processes in the application of insulating materials may be grouped as follows:

(a) Winding
(b) Insulating coils
(c) Applying windings to machines
(d) Processing after winding

As most of these are now familiar processes to practically everyone in contact with electrical machinery, only a few of the general phases will be dealt with. In the handling of electrical apparatus with reference to insulation, the main things to guard against are the elimination of moisture, the keeping of insulation materials clean, and the prevention of mechanical injury. The part which moisture plays in insulation difficulties, now very well known to those having to do with insulation testing and use, had to be evolved through many trials and tribulations, and with very considerable expense to both manufacturer and user. Without going into ancient history, it is perhaps sufficient to say that elaborate means of drying coils and completed machines, including very extensive vacuum drying apparatus, has been installed by the manufacturers of electrical machinery. Drying is effected by the application of heat in the ordinary ovens and by the vacuum drying process, the latter being especially efficient due to the fact that by placing apparatus in a vacuum, the boiling point of the contained moisture is very greatly reduced, and all vapors are removed from the oven by the vacuum pumps, causing the drying to be carried on in a very rapid and efficient manner. Following the drying, some sort of processing is necessary for practically all classes of insulation. This usually takes the form of varnishing or impregnating. The varnishes used are usually of linseed oil or tung oil base, frequently with the addition of certain varnish gums, the whole being brought to the proper consistency by the addition of a thinner, such as turpentine or benzine, which solvent must be evaporated during the processing. In the impregnating process, the more usual method is to use a melted gum, either mineral or vegetable, which is admitted to the vacuum chamber after the drying is completed, and without breaking the vacuum. This eliminates the possibility of entrapped air forming pockets during impregnation. Usually after the parts to be impregnated are thoroughly immersed, pressure is applied, which tends to drive the impregnating material to the innermost parts of the coil and insulation. Those who are not familiar with the change wrought by varnishing and impregnating

processes would probably be surprised at the amount of difficulty which occurred due to moisture inclusion prior to the adoption of these processes.

In the case of oil insulated transformers, it is now the usual practice to impregnate the transformer with transformer oil following the drying, as described for the impregnation of gum, this being done on the completed transformer, including iron terminals, etc. The transformer is then placed in the tank in which it is to be used, and unless the size is beyond that which can be handled by the railroads, the transformer is shipped complete, immersed in oil, with special precautions taken to seal the case against the entrance of moisture during shipment. Prior to the adoption of this plan, very elaborate drying equipment was frequently required at the place of installation, and many breakdowns have resulted from inadequate drying under difficult conditions. Installation troubles of this kind have practically been eliminated by the method named.

One of the most interesting developments in the manufacture of armature windings has been the application of what is known as the micarta process. This is a scheme invented by a Swiss engineer, whose patents and processes were acquired by the Westinghouse Company. The invention consists primarily in the wrapping of the coils by a sort of ironing action, the irons being heated during the time in which they are revolved about the coils, thereby producing a very tightly wrapped coil and the elimination of practically all air spaces. This process results in an insulating cell far superior to any which it was possible to produce by the older methods of wrapping and subsequent pressing. This process is used for the various types of wrappers ordinarily applied to armature windings, from varnished paper to cells containing a very large percentage of mica. This process has been largely responsible for allowing increased temperatures in certain classes of electrical machinery, and is one of the most efficient methods of producing what is known as Grade B insulation on armature coils.

A process which has come into vogue in later years, and which has proved of very great value in all machinery where it can be applied, is that of varnishing, by dipping or other method of application, the complete unit, that is, either rotor or stator of the machine. Properly done, this increases the ability of the machine to get rid of its heat, and is a very great aid in the keeping out of dirt and moisture.

Very considerable changes in manufacturing processes in connection with insulation have been brought about due to the use of the various synthetic resins now on the market. These materials have certain characteristics which are the exact opposite of the natural gums which they replace. Most, if not all, natural gums can be melted and remelted by the application of heat. The synthetic resins or gums harden by the application of heat and become infusible. This characteristic alone has brought about quite radical changes in various manufacturing processes. This characteristic of the synthetic resins is an extremely valuable one since materials can be manufactured which do not soften with heat. In this connection it should be stated that these materials are not fire proof or even heat proof in the sense in which the term is ordinarily used, but are subject to deterioration with temperatures not much in excess of those which ordinarily cause difficulty with the natural organic materials.

Insulation Research.

From what has been said, I think you will appreciate that our insulation problems are far from being solved, and that insulation research in many lines is extremely desirable. I am glad to say that this type of work is going forward with increasing impetus and an increasing realization on the part of designers and users of its importance. When my own work was begun on insulation, insulation was considered a necessary evil, and I often felt that the insulation engineer was considered a nuisance rather than a help. There was a continual contest between the electrical designers and those responsible for the insulation, and it often seemed that any space the designer could jockey away from the insulation man was considered just so much gain in the electrical design. Such jockeying not infrequently resulted in disaster both to the insulation man and to the designer if it was carried to a point where the space was inadequate. I am glad to say that this attitude is now a thing of the past.

The Engineering Division of the National Research Council have appointed a committee on insulation, and this committee is engaged in endeavoring to stimulate a study of the fundamentals underlying our insulation problems along all lines. The large manufacturing concerns have been and still are carrying on very extensive researches into various phases of the insulation work. The cable manufacturers have their own specific problems, where certain characteristics of insulation which are of not very great importance to the ordinary machine designer become of fundamental importance in the designing of cables. I refer to dielectric losses, power factor, etc. I have already stated that the problem of deterioration of insulation was one of great importance and difficulty. Studies along this line have been in progress in our own laboratory and elsewhere for many years and are still continuing. With increasing transmission voltages, with constantly increasing size of units, and the demand for more and more reliable service, with the bringing out of new devices which have their own special insulation problems, the amount of work to be done is very great indeed. We have our special problems in molded materials, in our ceramic materials, and in the application of insulation to the enormous coils necessary in the modern turbo generators and large high voltage transformers; we have the problem of elimination and keeping out of moisture, the problem of the effect of temperature, both constant and variable, and in some of our large structures the very important problem of relative expansion and contraction of the insulation in these structures with relation to the expansion and contraction of the rest of the structure. The modern static condenser presents a special problem somewhat similar to that present in connection with the manufacture of cables where the dielectric losses must be reduced to an absolute minimum and so maintained at all hazards. New methods of study and new apparatus for testing are being more or less constantly evolved. With each new method and new piece of apparatus the possibility of obtaining new and valuable data on old materials is made possible. The above statements are perhaps sufficient to indicate that the research work on insulation is only just well begun and

that there is perhaps no more fertile field for the research worker of the future.

Insulation of Steel Mill Electrical Machinery.

The insulation of electrical machinery for steel mill work presents almost identically the same problem as the application of insulation in general. There are certain particular difficulties in connection with steel mill applications due to the conditions under which such machinery must of necessity operate. Comparatively little can be done to make better constructions than those which are used for ordinary applications, because designers and builders generally endeavor to give the best they can for all applications. Where temperatures are especially high, as not infrequently occurs in steel mill practice, certain benefits can be obtained by more liberal use of the higher temperature insulation, such as mica and asbestos. Unfortunately, the use of these materials gives an added problem in connection with the keeping out of dirt and moisture. Asbestos is notoriously a relatively poor insulating material both from the electrical and the mechanical standpoint, and is very prone to absorb moisture unless processed with a material which tends to keep this out. The available materials for moisture-proofing are limited to those of the organic classes, none of which will stand temperatures even approaching that which asbestos is capable of withstanding without injury. Consequently, here again a compromise structure results from the use of asbestos. Similarly, mica must be applied by the use of varnishes, such as shellac, and must be held in place by tape, such as the ordinary cotton tape so largely used for insulation work. Asbestos tape in limited amounts is available, and this is very considerably used in special high temperature applications. With a full knowledge of the limitations of insulation generally, much can be done in the laying out of machinery for steel mill work to provide locations and protection which will gradually aid in the life of the machines, and every facility should be provided for the keeping of such machinery in as good condition as possible with regard to dirt, moisture, and temperature. Where the conditions are especially hard, as, for example, on a charging machine, the life of the insulation may be considerably reduced, and in such cases as perhaps also in a considerable percentage of steel mill applications, provision should be made in the design for the extremely quick substitutions for damaged machines when damage does occur.

As has already been stated, the chief enemies of insulation are dirt, moisture, and temperature. In many applications of steel mill machinery these conditions are especially aggravated of necessity, especially where mills are more or less open, where the conducting dirt is especially plentiful, and where temperatures from the steel mill processes are unusually high. About all that can be said in this connection is that the designer should provide every reasonable protection from these elements, and the operator should take every possible precaution to see that machines are protected from moisture, that they are kept as clean as possible under the circumstances, and that provision is made for keeping the temperature within the temperature limits set for the class of machines used. With reasonable attention to these points, there is no reason why steel mill electrical machinery of the modern type should not be as reliable as electrical machinery for almost any other application.

DISCUSSION

R. S. Shoemaker*: Mr. Chairman and gentlemen: I am doubly glad in being here tonight; first, to renew a number of old acquaintances, and to meet a number of you men that I have not met before; secondly, because this is my home city; this is where I was born. I don't know that that is any great credit to the City of Philadelphia up to date, but still there is hope, possibly.

It is pretty early in my administration to be able to tell you a very great deal about our plans for the coming year; however, there is one thing I wanted to speak to you about first, and that is our new publication. I guess you have all had your copy by this time of the Iron and Steel Engineer.

We have had some very encouraging reports since its publication, and, after all is said and done, this association is going to live very largely by what we put down on paper; in other words, it is our yearly proceedings and our monthly proceedings that go down as a permanent record of what we stand for and what we have done. Our first January issue I think is a credit, but we have got to keep up that standard. I want to make a plea to this Philadelphia section to help us all you can. A number of you oftentimes have things come up at your plant of not enough consequence to write a paper about, but our secretary would be mighty glad to have such material. The life of most any publication, as you all know, is in the advertising. You can all help on that. Wherever you see a chance to obtain some advertising, communicate with our business manager.

During the year we hope to do some real constructive work on standardization. Over the past number of years we have had more or less success, possibly less than we should have had. Last year at our Buffalo Convention, at a directors' meeting, we decided to communicate directly with the presidents of the leading steel companies, in fact, with all the presidents of the steel companies, and we are just starting now; we have not sent out all the letters, but we have written a number of them, asking them to appoint a man or men, preferably in their electrical department, to take an active part in standardization work. The replies we have had so far are very encouraging. Some of you men here will undoubtedly be appointed on some of these standardization committees, and I want to ask for your co-operation and that you try and attend the meetings. Some of them will be in Pittsburgh and some in other cities, and this year we want to do more on standardization work than we ever have before, and I feel sure we can if you all help. I think we are getting away to a very good start.

The next thing of importance, I think, this year is going to be our meeting in Pittsburgh in April — our combustion section. The combustion section of this association has been going ahead very rapidly in the two or three years that they have been organized. This year we are going to have a two-day convention or conference in Pittsburgh on fuel saving. A good many of you electrical men are vitally interested; some of you not quite so much so but we want to ask your co-operation. We want you to attend if you possibly can. We are going to visit some very important and interesting plants in the Pittsburgh district, so it will

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be well worth your time to come to Pittsburgh in April for this meeting.

Our national convention, as most of you know, will be held in Pittsburgh this year. There is not a very great deal I can say about it at this time. One of the main committees, the committee on general arrangements, banquet, etc., caring for the ladies, entertaining them and so on, is very active. Mr. John Standing is chairman of that committee, and he has assured us that we will have a real time, socially as well as technically. On the technical side we have already arranged for some very excellent papers, and I think you should start now to make your plans for Pittsburgh in September. The convention hall will be Duquesne Garden, which offers every facility for a very good exhibition.

Mr. Chairman, I won't take any more of your time; it is getting late, and I know you are all anxious to hear Mr. Skinner's paper. I want to thank you all for the privilege of addressing you, and hope that I will be able during the year to get better acquainted with all of you.

A. J. Standing*: Mr. Chairman, I do not know that there is much to add or that much discussion can follow a paper as complete as Mr. Skinner's. It has been very interesting and has given a great deal of food for thought.

From the operating standpoint in a steel mill, we have, as Mr. Skinner says, particular problems in the way of insulation due to the inherent nature of our operations. Touching first on transformer oils, the requirements we expect are that they shall be highly dielectric and as free from sludging as possible. Oil elsewhere than in the transformer is responsible for about 75 per cent of our trouble, due to the fact that oil getting on the commutators and coils of motors produces a very rapid deterioration of the insulation. I think I am safe in saying a large percentage of our armature troubles have their origin in the grounds to commutators, which many times can be traced to the presence of oil.

The problem of painting and varnishing is one that requires considerable thought. When the pressure of work is heavy you have to get armatures out of your shop and back on the job as quickly as possible. When business is not very brisk you have a chance to use your bake oven; and I think one thing we arrived at was the fact that it is best to bake armatures before you apply your baking varnishes; in other words, to try and drive out the moisture before applying, and then put your varnish on as hot as possible and bake afterwards.

As regard the care of armatures on machines like cranes, it is always better for us to change the armature or motor quickly, thus avoiding the delay that we would occasion by taking the machine out of service and nursing it along and cleaning it and taking care of it. That, of course, does not hold true with regards to large mill drives. There the unit is of such great importance it is necessary to take it out of service and clean it and bake it periodically. One case we took care of recently was a 2,000 hp. motor. We gave it a thorough cleaning and drying with the motor right in the mill house. It was covered with dust and dirt which naturally would not blow off, as it was stuck there with a film of moisture, oil, and one thing and another. We resorted to the use of brushes, but in watching the brushing process I very soon found that a good deal of the varnish was being brushed off the coils; and as soon as we saw that, we resorted to our spray paint and then heated up the room.

Another question is with the other motors that are used for table drives in mills in cold weather. These are the motors Mr. Skinner spoke of in connection with the contraction and expansion. When the mill starts in the morning, the motor is cold and unfortunately the mill is cold, and your starting loads are extremely high. That means that the temperature of the motor from a purely current standpoint is increased at a very rapid rate during the start of your mill, and after the mill is in operation, you then have your subsequent temperatures increased due to the presence of the hot metal. The question of summer temperatures in steel mill operation has some peculiar features; this is particularly true in regard to screw down motors on blooming mills. These motors are one of the most important units, they naturally are in a position to receive the maximum amount of heat from the rolling operation, and the tendency is for the temperatures to become so high that it is a question whether continued radiation takes place. In some cases it is really preferable, I imagine, to resort to artificial cooling.

I do not believe I can add anything further except to congratulate Mr. Skinner and our Section on the very able paper we have enjoyed.

Fred H. Woodhull†: I don't know, Mr. Chairman, that I have anything particular to add to what has already been said by Mr. Standing, except to emphasize the point along maintenance lines in connection with cleaning and re-varnishing the apparatus in service. It might be done periodically with whatever method is used. I was wondering in cases where such treatment is given the apparatus, what is used for cleaning. I think Mr. Skinner could enlighten us on that matter.

George W. Richardson‡ Mr. Chairman, I was very much interested in the lecture, but I do not know that I have anything to say, except Mr. Woodhull asked the question I was going to ask, and that was relative to a cleanser for cleaning a large machine, say a generator, for instance. I have to take mine apart every once in awhile and clean it up. I am afraid we are liable to cause more damage by cleaning, with brushing, as Mr. Standing has said, than by leaving the original dirt on the machine. I was surprised, one of our generators, that is, turbo-generators, the first six months we had it, was almost enclosed in with dirt. There was so much work going on around the plant at the time, and so much oil being thrown out from the bearings, that it caused a considerable lot of dirt. I want to know if there is any good material for cleaning, so that we won't do any harm to the armatures while we are cleaning them. We do not have these facilities, of course, for drying as they do in the manufacturing plants. The small armatures in our plant we dip. We dry them and heat them all over, and then dip them into the varnish and then dry them again. We dip the whole armature, commutator, and all, and we get better results than we did before we undertook to do this.

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‡Superintendent Electrical Department, American Bridge Co., Pencoyd, Pa.

P. T. Vanderwaart*: Mr. Chairman, our Association is indeed fortunate in obtaining for its records this paper delivered by Mr. Skinner; a paper very interesting historically and full of practical information applicable to the present day insulation problem.

It is of interest to note that the live Philadelphia section obtained this valuable paper from the Pittsburgh district. Possibly after Mr. Kelly returns and wakes up the apparently dead or sleeping Pittsburgh section, it will be more difficult for the Philadelphia section to get such good papers.

I remember that at the first meeting I attended of the Philadelphia section of the Association of Iron and Steel Electrical Engineers, I was impressed by the practical discussion of the paper. I believe that our discussions are more complete than will be found in a good many meetings of technical societies. It has always been my endeavor when I go to a meeting knowing what the subject is to be, to bring some particular thought as closely related to the subject as possible, and I believe the success of any society depends upon a similar attitude on the part of all the members.

The thought which I had in mind to bring to your attention tonight is one which may be of interest to you. It has to do with asbestos insulated wire. I have here a sample of No. 14 twisted lamp cord with N. E. Code Type SB 600-volt Deltabeston insulation. There is no rubber in it. We use these drop cords for lamps in certain parts of our plant where we have quite high temperature. It so happened that we had an occasion to wonder what would happen to this wire if it was subjected to extreme moisture. I will pass this wire around so that you may get an idea of what it is like. (The wire was passed about the audience.) The twisted wire, four feet long, was immersed in water and a record kept of time and insulation resistance. The insulation resistance dropped quite rapidly during the first few minutes. The dry resistance was 135 megohms between the two wires four feet long. After six minutes of immersion, the resistance had dropped from 135 megohms to 40; after eight minutes to 22; after nine minutes to 16; at the end of an hour the insulation resistance had dropped from 135 megohms to 0.5 megohms. That is a tremendous drop, but still this is a safe insulation. The resistance continued to drop fairly rapidly for five hours. Then the decrease became noticeably less rapid and finally it became constant. At the end of the five hours the resistance was 75,000 ohms. At the end of one week the resistance became practically constant at 20,000 ohms.

J. R. Penman†: Mr. Chairman, I do not think I can add anything to the paper. When I started up there in Reading we made it a rule every week to have all the men there on Sunday, and we cleaned all the motors and all the controllers. But the motors started to grow in number much faster than the men ever grew in number, and finally we could not clean all the motors on a week-end. At the present time we are lucky to be allowed a man at all in the plant on Sunday. We cleaned them the best we could, but never re-varnished or re-insulated unless they went into the shop for some other purpose. For the last two years we have done very little cleaning or bringing anything in that has not broken down. Our production governs the amount of men we are allowed, and when production is not very high, the men are in the same proportion.

George J. Walz‡: We have at the plant with which I am connected, a large main roll reversing drive d.c. motor, about 15,000 hp., which has been in operation over three years. At the same rate of wear of the commutators, which has taken place in the last three years, assuming that this same rate of wear would continue in the future, those commutators on that set would last about 50 years, easily. The cost of replacing and renewing the bearings, brushes, etc., is negligible. We know that the iron and the copper is not going to wear out of any account, so that brings us up to the insulation, which, in the final analysis, determines the life of this set, which represents an investment of several hundred thousand dollars. Of course, we keep this insulation clean, and it is never overheated. You can readily see if there were some method by which we could do something to that insulation, say every month or every year, which would prevent it from deteriorating, that the life of that set would be pretty close to half a century.

I would like to ask Mr. Skinner whether he knows of anything that we could do as we go along, before the machine gets old, that would accomplish that? The machine has insulation of the most modern design and presumably of the very highest grade, having been manufactured by his own company. That is the only part of that equipment that we cannot take care of, except to keep it clean and varnished, because we do not know how. You can readily see that it would pay us to spend, if necessary, thousands of dollars a year to accomplish such a thing, if we knew what to do.

George H. Schaeffer*: Mr. Chairman and gentlemen: I have been greatly impressed by the paper, and feel that it is a great privilege to hear a man that is a pioneer in the field so completely discuss it. If I can remember just a part of what he says, I think I will know something about insulation. I was particularly impressed by the statement that Mr. Skinner made as to the proper application of the different classes of insulation. I believe that some of our problems would be solved if we had the proper application of the different classes.

I think Mr. Skinner has shown that he is a broad minded man by giving a formula for eliminating our troubles—when in doubt, knock off and go to the show. I want to thank Mr. Skinner for that valuable formula, and I promise I will remember it.

R. S. Shoemaker: Mr. Chairman and gentlemen, we certainly have listened to a very splendid paper. Mr. Skinner is to be highly complimented, and this Association is to be complimented in being able to draw here a man who has an international reputation. When you think of insulation, you think of Mr. Skinner right away as being a world authority.

I was very much interested in all the details of this paper, and one thing in particular interested me. He said that the research on varnish is still going forward; that it has not yet reached the end.

Within the last year we had occasion to rewind a modern motor, 2200 volts, 1200 hp. It was slightly damaged and we thought it was just a matter of lift-

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ing a few coils here and there, so we prepared to lift the coils, but they would not come. We tried all known means and methods of persuasion; we tried to heat with current; then we sent to the boiler shop and got an air chipping hammer, and we took the coils out and we did not get a piece three inches long. I don't know how those coils were put in, but I assume that they must have been wound and then dipped and impregnated and baked with tremendously hard varnish. If the research is going to help find any harder varnish, I hope the research is not successful.

I am going to be perfectly frank, I don't know how to clean our motors. We are going to learn the proper way to do it I hope from Mr. Skinner when he answers the question just asked. I have been in the dark just the same as the rest of you. For several years we have made a regular practice of cleaning our large mill units each six months with gasoline and air, thoroughly washing down the windings, later applying a good coat of air drying varnish. That is probably against all rules, but it has worked up to date. It is the best method I have ever found, in fact, it is the only method by which you can remove the mill dust, oil and grease which collects on large units.

Joseph S. Rowan‡: Mr. Chairman, speaking about the research on varnish work, I think it would be a good idea to instruct the varnish salesmen to be more frank with the customer as we really have not had a thorough satisfactory one from any of them. I was glad he was so frank as to say there was so much more to learn, and I am glad they are keeping on with their work.

Walter C. Kennedy§: Mr. Chairman, I don't believe there is anything I can add, only I appreciate the opportunity of saying that I have certainly enjoyed the paper, and I think not only the Philadelphia section, but the Association in general should feel very grateful for it. Our president, Mr. Shoemaker, made the remark that our Association, in future more than ever before, is going to be judged by what it puts down on paper; so I think, if that is the case, and I firmly believe it to be so, we certainly have something tonight to put down on paper and to be proud of, to be published in our proceedings. We have three different kinds of papers, all of which are interesting—some naturally more than others. Some are pure operating problems which we can digest at the meeting, and then there are other kinds of papers that we like to take home and think over, which make very valuable reference papers, and I think that is the kind of a paper we have had this evening.

There are one or two questions that I wanted to ask. One was for a little more information about asbestos insulation. Mr. Skinner mentioned something about the compound used for a binder in asbestos not being nearly as good as the material itself. Another was, the information about the synthetic resins. I would like to know whether the type of insulation that we hear so much of, or have heard so much of in the past—bakelite varnish—is what could be called a synthetic resin, and is that being used to any extent, or could it be applied in an ordinary repair shop for dipping and baking armatures and other parts of apparatus. I understand that can be made in the form of a liquid, and then after it is heated it gets hard and gives that material which is commonly called bakelite.

P. A. Topper*: Mr. Chairman, and members of Iron and Steel Electrical Engineers, it is my pleasure to be with you here tonight as a guest, and as I am not connected with the iron and steel industry, but am in paper mill work, I did not expect to be called upon. I am unprepared, and feel quite incapable of adding anything of value to this discussion; however, I will say that we have insulation problems, probably, of a different nature. Our chief troubles are caused by chlorine gas fumes, moisture and salt atmosphere.

We have our own repair shop for rewinding and making general repairs, and our method, to date, is to wash the coils thoroughly with gasoline (when repairing an old armature) then placing it in an oven at 210 deg. F. When hot it is dipped in Westinghouse Amber Baking Varnish, then baked for forty-eight hours. When removed from the oven, and while still hot, a coat of air drying insulating paint is applied, which on cooling leaves a smooth glossy surface. This method has given fairly good results.

I have listened to this discussion with much interest, and feel that I have profited by it, and believe I can put to practical use, in our plant, some of the information so ably presented here tonight.

C. N. Johnson†: Mr. Chairman, I have enjoyed the paper very much. I think there is one thing which the various remarks of the operating men have brought out, which applies not only to steel but to every industry. It is the necessity for a regular routine of inspection, cleaning and proper care of the electrical equipment. The insulation is one of the weakest points and its life may be greatly extended by careful handling.

Edgar O. Oeters‡: Mr. Chairman, I came here for information just the same as the rest of you, but I think the paper is all wrong in being read before a group of men like you; you who know what the requirements are. You should have brought here all the purchasing agents and their assistants who buy this material purely on price and not on quality, so that they might learn of the uses and strains to which the various insulating materials are put, and that 5c a pound saved in buying cheap insulation might result in delays and repairs that would cost many hundreds of dollars and therefore the best that can be obtained is the cheapest in the end.

Frank Hollingsworth: Mr. Chairman, it was a very interesting paper this evening, and one question that occurred to me was whether there had been any research work on the effect of salt on insulation. In the plate rolling mills we use a large amount of salt which affects both copper, and insulations of motor and other electrical apparatus.

In regards to general routine work in the plant, we make it a practice where possible of periodically bringing the large motors to the shop for cleaning and painting and find it is a great help in maintainance.

W. Burr: There are two questions that I would like to ask the speaker. One of them is, do you recommend using the same voltage for break down tests on equipment that has been in service when it is taken

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out for repairs as is used on new equipment, or do you feel that you are safer to omit the break down test due to the fact that you may injure the insulation by applying such high voltage?

I would also be interested in knowing the present process of drying out large transformers which are too large to be shipped to their destination in the oil enclosed case.

Arthur Allen*: Mr. Chairman, this has been an extremely interesting occasion to me. I have known Mr. Skinner over 30 years, back in the eighties and nineties. When Mr. Skinner was in the laboratory studying and bringing out the early developments of the insulation problem, I was on the road, practically trying out his insulation; and I can add, with all degree of truth that as the voltages increased and the size of the machines increased as they did, very rapidly in those early years, the question of insulation was very satisfactorily met as a general rule. Of course, when machines got on the ground we had some breakdowns at times, but we generally could find a cause for this and they were corrected.

There is a question that comes to my mind at the present time, and I think the Association would be interested. It is with regard to the present condition of the insulation problem as applied to the temperature rating of machines. On the original machines the question of temperatures did not enter to any great extent. If the old machines heated up to 30 or 35 degrees, it was considered to be a dangerous point. Later, the standard was arrived at of 40 deg. basis as the temperature basis for the rating capacity of the motor. That went along for quite a number of years and with quite satisfactory results. As you all know, there was a change. We were all told, as practical men, with considerable blare of trumpets, that a 50 deg. machine was an entirely satisfactory machine from the insulating point of view, and that there was no reason why a 50 deg. machine should not become a satisfactory standard. But I think all those present will agree that the 50 deg. basis for the rating of machines has not proved satisfactory; and that is further concluded by the fact that the present new rating, which has been put out by the powers that be, is a 40 deg. single rating basis. It may be that the 50 deg. basis was not satisfactory, and probably was not satisfactory due to the insulation problem which came up in the practical operation of these machines. Now, we come back to a 40 deg., or what is termed a 40 deg. single rating basis, and I would be interested to have Mr. Skinner advise, what, if any, difference in the insulation problem entered into this new rating. Undoubtedly, a 50 deg. machine has got to be better insulated, so far as the dielectric insulation is concerned, than a 40 deg. basis. I would like to know just what developments are in progress in the new rating of the 40 degree single basis.

N. A. Bodey†: The question of cleaning motors has just brought something to my mind. I happen to be in the candy business instead of the steel business, but we have just as many problems, if not more problems, in the way of upkeep on motors. Most of these are due to starch, sugar and lubricating oil. Our lubricating oil problems have been due mainly to the pumping action, due to the construction of the bearings, particularly on the old Westinghouse type CCL motor.

Our cleaning during the past eight years, has been accomplished by the use of air and gasoline under air pressure. During the last year, we made a change due to the danger of using gasoline about the plant. Due to the impossibility of removing the greater part of sugar and starch from the windings of a motor, we have tried a stunt which is possibly against all the rules and regulations. We use a spray of warm water on the coils to dissolve the sugar, then dry them thoroughly. If the motor is oil soaked, it is then dipped in carbon tetrachloride and allowed to soak for a short period, after which it is thoroughly dried. Carbon tetrachloride is very destructive to some insulating materials, however, motors treated in this manner have been in service for over eight months, and the process is apparently satisfactory.

Geo. H. Schaeffer‡ I would like to have an expression of Mr. Skinner's opinion as to the regular ohm meter test on machines. Another question is, is it possible for the moisture to get into a water cooled transformer on account of the water pipes?

C. E. Skinner: Mr. Chairman, I certainly feel highly complimented that this effort has brought about so much discussion. That is what I intended to do. I wanted to make you think about some of these things, and also to ask questions, which I would answer if I could.

I think the main discussion has centered about the cleaning and care of motors, and I will try to answer that and try to cover all classes. As far as I know, there is no set way to clean a motor or a piece of electrical machinery. It depends on what you have on it.

One of the last gentlemen spoke of starch, sugar and oil. That is a combination I never ran into. I thought I had them all. I think he has probably hit the best method for that particular lay-out, perhaps as good a one as could be devised. The structure has a good deal to do with it. The dirt gets in places that you cannot reach with any mechanical cleaning, and it is a very difficult problem. The mechanical cleaning, brushing and so on, has to be done with a great deal of caution, as has been pointed out. You can very easily do more harm than good. Cleaning by an air blast must be watched carefully, and it is important that the air going into the machine be perfectly dry. I have often seen our own machines soaked with water when we were using an air blast. You can get dry air only by some drying method in your compressor system. Perhaps one of the best methods for general cleaning, when it can be done, is that outlined by Mr. Shoemaker, that is, the use of gasoline. In a great many cases the materials or dirt is in combination with the oil, and nothing short of an oil solvent will overcome this condition.

In the case of Mr. Walz's 15,000-hp. motors, the precaution has been taken to use washed air. That was one method I was going to speak of, as it is undoubtedly the best way to protect a motor. I am sure I hardly know just what advice to give, but perhaps again, Mr. Shoemaker's method to clean with gasoline, then revarnish, is as good as any if it can be applied.

I have a lot of notes, some of which I cannot make out; but one to which reference has been made is the question of baking the varnish film harder than

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‡Electrical Engineer, Carpenter Steel Company, Reading, Pa.

usually is done. There again we are between the devil and the deep sea. While the motor is in service, you want the insulation as hard as possible to resist mechanical abrasion as well as the effect of the elements; but when you want to make repairs it is desirable to be able to soften up the coils so they can readily be removed. We would like to wind coils so that they need never be removed, but that is not always possible.

The question has been raised about the application of bakelite. I might say that in the early days of bakelite, we conceived a bright idea; we found that by using bakelite and very finely powdered silica, we could make a cement that was a corker; so we made a trial job on a bunch of railway motors. Unfortunately, it turned out later, these motors went to Los Angeles, a good way from home. We had a breakdown on one of those motors, and received a telegram asking what sort of stuff this was anyhow. Two or three cold chisels had been worn out in trying to chip it out. This customer was worse off than Mr. Shoemaker. In general, I would say that bakelite and condensation products are rather difficult to handle. We have used very large quantities in various ways, and I do not recall a single application that we did not have to do some experimental work with and usually some kind of trouble developed before the problem was solved. If you undertake the use of bakelite or condensation products, I advise you to do so under the scrutiny and advice of the manufacturers. Without some knowledge of the way you are working this material, you are liable to get into more trouble than you previously experienced.

The question was asked about the effect of salt. Well, salt is just about as bad as anything you can get. That kind of material is very destructive and very hard to take care of. We have run into more than one case of trouble due to the necessary use of salt around certain of the steel mill operations, and the care there, I think, is to devise some way, if we can, of keeping the stuff out. If you get it in, in some quantities, I think you are up against a case of trouble.

The question of voltage on old repair stuff has been discussed. In the early days of dielectric testing, this was a subject which nearly disrupted our Engineering Department. We are doing the repair work for our customers at East Pittsburgh, and they insisted that the tests should be made in accordance with the rules. The rules required a voltage test approximately the same as the original test. In many cases, when it was necessary to turn a commutator or replace a burned out coil, the armature failed in some other place when the meter test was made. Of course, it was necessary to repair the new failure, and when we charged the customer for the complete job, he naturally felt that we were taking advantage of him. This condition really brought about testing the repair stuff.

The question was asked about the protecting of transformers too large to ship in oil. The scheme for that is to keep the transformer as dry as possible and follow the plan I mentioned in connection with the early Ontario Power Company's transformers, that is, to do a pretty thorough job at the place of installation, by equipping as best we can with heating apparatus and vacuum drying.

I am sorry I have to take a little bit of a fall out of my friend, Mr. Allen. The only change from 50-deg. to 40-deg. continuous rating was on general service motors and that was brought about, not by any engineering consideration whatever, but by a commercial situation. At the meeting of the International Electrical Technical Commission in Geneva, in the latter part of 1922, the Continental European companies objected strenuously to any advocacy of a change from the 50-deg. rating, and practically all machinery at the present time, that is all large machinery, and a very considerable percentage of motors, are now rated on the 50-deg. continuous basis.

The question of banding was referred to. I believe that there is no one relatively small process carried on in the manufacture that requires as much skill and practice as that of banding, simple as it seems, and all sorts of schemes have been tried to determine the tension at which bands should be put on. About all I can say is that caution should be taken for protecting the insulation from the cutting effect of the band, and the band should be put on tight; if it is not, it is not much use to put it on.

I think it is really a good scheme to follow up the machinery, particularly with the idea of measuring insulation resistance. If the machine is getting particularly dirty or moist, and you can catch it, you will find that test to be extremely valuable in itself. For instance, on a large machine, if you wet your finger and draw it across the commutator to the iron, you might get a very low reading and yet the machine would be in no danger, so you have to take these readings with a considerable degree of caution and as indications.

The question was asked as to whether water can get in water cooled transformers. In the early days of the water cooled transformer, we got into serious trouble due to the fact that the end of the coil was not lagged, and the cold water in the warm atmosphere over the transformer would condense the water in the coil, and that would drop down into the transformer, and in most every case breakdown has occurred from that cause. In modern transformers the coils are supposed to be thoroughly lagged, heat insulated at least on the incoming end of the coil that is exposed to the atmosphere, and that should take care of any condensation there. But if you have an atmosphere above the coil which contains moisture, you have a coil there that is exposed and it is inevitable that there will be condensation there.

Again, gentlemen, I wish to thank you and to say I very greatly appreciate your discussion. There has been some discussion here about whether or not certain individuals are better citizens of certain places than others, which reminds me of my German friend who said, in discussing Americanization, "I am a better American as you; you were born here and could not help it; I came here and was naturalized."

The membership of the Association of Iron and Steel Electrical Engineers will be shocked to learn that B. G. Beck, Resident Electrical Engineer, American Sheet & Tin Plate Company, at Gary, Ind., died Thursday, April 18, 1924. Mr. Beck joined the A. I. & S. E. E. in 1908 and was an active member in all the association's activities.

Electric Power at Portsmouth Works of the Wheeling Steel Corporation

By H. C. MOSLEY* and R. H. ROGERS†

AN average of 200,000 kwh. per day is generated and used in the production and manufacture of steel at the Portsmouth Works of the Wheeling Steel Corporation. With the exception of an average of 50,000 hph. in steam engines and mechanical drive turbines, this constitutes all the power used in this plant which turns out some 38,000 tons of steel per month. Fig. 1 shows a 150-ton four girder ladle crane and crew pouring ingot molds. The product is shipped as forgings; black, high finished, electric and galvanized sheets; jobbing mill plates for auto side frames, tie plates, steel barrels and range boilers. The Rod and Wire Department produces all sizes of rods and black or galvanized finished wire products such as barbed wire, field fencing, nails, rivets staples, etc. All these products are derived entirely within the plant from the iron ore.

At the left is Mr. H. C. Mosley and at the right Mr. R. H. Rogers, authors of the paper.

The Portsmouth Works extend for nearly two miles along the north bank of the Ohio River, with the operations running from east to west. The eastern portion is occupied by the coke plant, blast furnace, ore storage, power house, pump house and pig casting house. The central portion is given to the open hearth furnaces, blooming, jobbing and 18" continuous mills, the principal electric substation and auxiliary power house. The new Rod and Wire Department and the various manufacturing shops take up the western third of the works. The water front is shown in Fig. 2 looking west. Water transportation is an important factor here.

Ore is received by rail from Lake ports, lime stone from central Ohio, and coal by the Ohio River from the Companys mines to the east. Shipments are made both by rail and water, the latter giving an economical route to southern markets. The coal handling equipment shown in Fig. 3 is motor driven and nearly automatic. About 1,400 tons of coal is handled daily.

General Power System.

The electric power system is 3 phase 60 cycle made up of two primary turbine stations, a transformer station, two a.c.-d.c. substations, approximately 10 miles of 11,000-volt and 2200-volt transmission lines and 46,000 hp. connected load in a.c. and d.c. motors.

The seven turbine generators range from 12,500 kw. to 500 kw. aggregating 21,000 kw. capacity. Power is distributed at 11,000 volts and 2300 volts a.c.; 600 volts and 250 volts d.c. The motor generator sets are all synchronous motor driven and aggregate 8,250 kw. in seven units in from 3,000 kw. to 750 kw. output.

There are three 4,200 kva. 11000/2200-volt single phase oil insulated, air cooled transformers of the outdoor type located near the center of the plant and several small transformers in the manufacturing departments. Motors range from 5,000 hp. to 5 hp. in a.c. and d.c., there being 1,050 in all.

Main Power House.

The principal generating plant known as No. 2 Power House is located near the blast furnace in order to utilize

FIG. 1.

*Chief Electrical Engineer, Wheeling Steel Corporation, Portsmouth, Ohio.

†Industrial Engineering Department, General Electric Company.

blast furnace gas for boiler firing. The power house is at the left of the chimney in Fig. 4 with boiler house, blast furnace and ore storage at right. Tracks in foreground lead to the pig casting house. The boiler house contains eight 833-bhp. water tube boilers, seven active of which four are gas fired and three coal fired using automatic stokers. Thus four-sevenths of the power generated is from blast furnace gas. Steam is held at 200-lb. pressure and 100 deg. superheat.

The turbine room contains a 12,500-kw. unity p.f. 11,000-volt 1800-rpm. turbine generator and two 3,000 kw. .8 p.f. 2200-volt 3600-rpm. turbine generators. In Fig. 5 the details of the turbine end of the 12,500-kw.

FIG. 2.

11,000-volt turbine generator are clearly shown. Two motor-generators with T100 hp. 2200 volt synchronous motors and 750 kw. 250 volt d.c. generators furnish power for d.c. motors in the immediate vicinity. Two turbo blowers of about 2500 hp. capacity each furnish air for blowing the blast furnace. Two 3000-kw. turbine generators and two 750-kw. motor-generators are shown in Fig. 6. The turbo-blowers are in the left background. The usual auxiliaries are located in the basement together with the motor driven pumps for gas washing. The total electrical load on this station is 18,500 hp.

Auxiliary Power Station.

No. 1 Power House is in the central portion of the plant 800 ft. from the transformer substation to which it is connected by a concrete tunnel. There are two 500 kw. 250-volt d.c. turbine generators in this station and two 1,000-kw. 2200-volt a.c. turbine generators are being installed. The switchboard equipment for the transformer station is located in this power house and all control and feeder circuits are run through the tunnel mentioned. A 1500-kw. synchronous motor-generator delivering 250 volts d.c. completes the equipment in this station.

Transformer Station.

Between a heavy steel tower and the switch house are three 4,200-kva. 11000/2200-volt transformers of the oil insulated air cooled type. The switch house contains a particularly well designed system of switch cells, bus

FIG. 3.

compartments and remote operated oil switching gear, a portion of which are shown in Fig. 7. The tunnel underneath connecting with No. 1 Power Station carries all the interconnections and the main supply buses.

Number 1 Substation.

A 2300-volt synchronous motor-generator delivers 750-kw. d.c. at 250 volts to the barrel and tank shops and to the coal dock and other water front machinery.

Rod and Wire Mill Substation.

A new 45 x 125 ft. steel and brick building houses the Rod and Wire Mill sub-station equipment toward the west end of the plant. The rotating machinery is installed along one side of the building and the switchboards along the other side 12 ft. from the wall and 19 ft. from the machines. A 15-ton double hoist electric crane serves this room and the roll shop at the end. Machinery foundations extend down through the basement and they

are of box form with entrances. The main Rod Mill is adjacent on the machinery side.

The following equipment is located here: A three unit synchronous motor-generator having two 1500 kw. 600 volt d.c. generators one at either end of a 4,200 kva. .8 p.f. motor and all on a common bed plate Fig. 8; a 2,870/1435 hp.-400/200 rpm. 600 volt d.c. motor which drives the Roughing Mill; three 800/355 hp. 706/320 rpm. 600 volt d.c. motors, one for intermediate stands and two for finishing stands. The 2,870-hp. Roughing Mill motor in Fig. 9 has a 2:1 speed range.

Excitation is furnished by a 90 kw. 2200/250 volt a.c.-d.c. motor-generator. Two motor-generators of 750 kw. capacity at 250 volts d.c. driven by 1100 hp. .8 p.f.

FIG. 4.

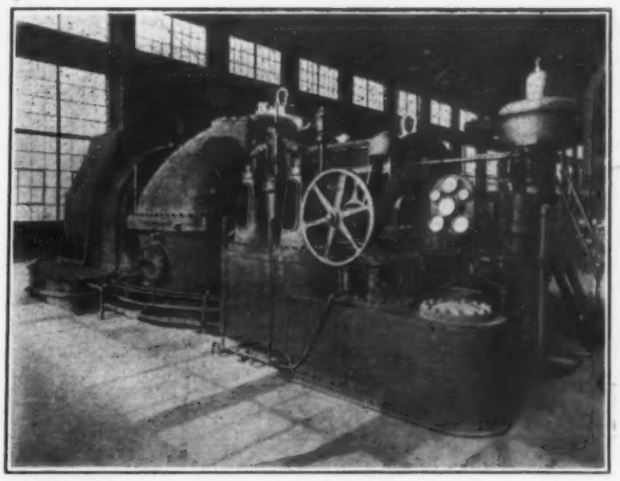


FIG. 5.

synchronous motors furnish power for the cranes and the Wire Department motors.

The a.c. general service motors are supplied by three 400 kva. 2200/.110/220 volt single phase transformers.

The switch-board is lined up so that its units come opposite the machinery concerned, thus allowing straight line wiring through the basement from panel unit. The 3,000-kw. three unit and the mill motors are handled by a nine panel board. Four magnetic control boards take care of the 2,800-hp. and 800-hp. motors. A 12 panel board accommodates the incoming feeders and the d.c. output from the motor-generators as well as the transformer feeders. Open spaces screened between panels provide for future extensions. Fig. 10 is a view in the Rod and Wire Mill Sub-station, a fine example of steel mill practice.

Daylight is admited through high windows along the south wall and by windows between the high and low bays of the roof. A unique feature of this station is the five Corinthian type lamp posts in the main aisle each carrying two 300-watt lamps in opal globes. The night lighting is thus particularly well placed and ample. About 50 tons of conductors were used in tubes across the basement ceiling between panels and machines.

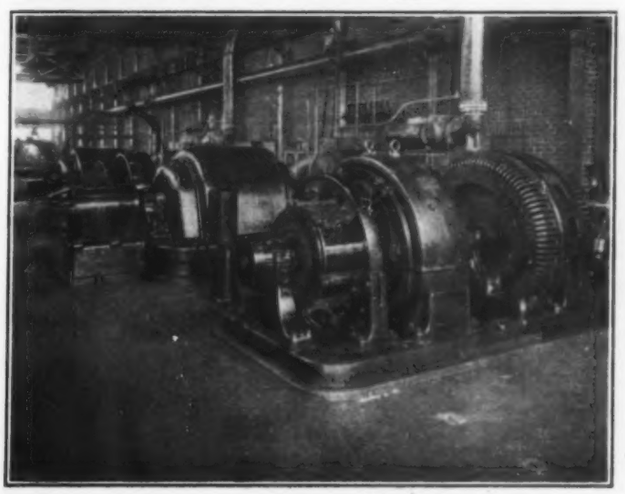


FIG. 6.

Transmission System.

The transmission system between the main power house and the transformer station is carried on steel towers, while the principal lines west to the manufacturing section is on a high pole line. The 11,000-volt line is of 600,000 cm. wire from the main power house to the transformers. On the same towers are three circuits for 2200 volt service over 300,000 cm wires. A 600,000 cm 2200-volt circuit runs from the main power station to the pump house at the river bank. The coke works is supplied with about 500 kw. through a 4-0 circuit.

The 12,500-kw. and the two 3,000-kw. generators at the main power house are paralleled on the 2200 volt side of the transformers and power is distributed throughout the plant from a common bus by means of remote controlled oil circuit breakers. The principal loads taken off this bus, follow:

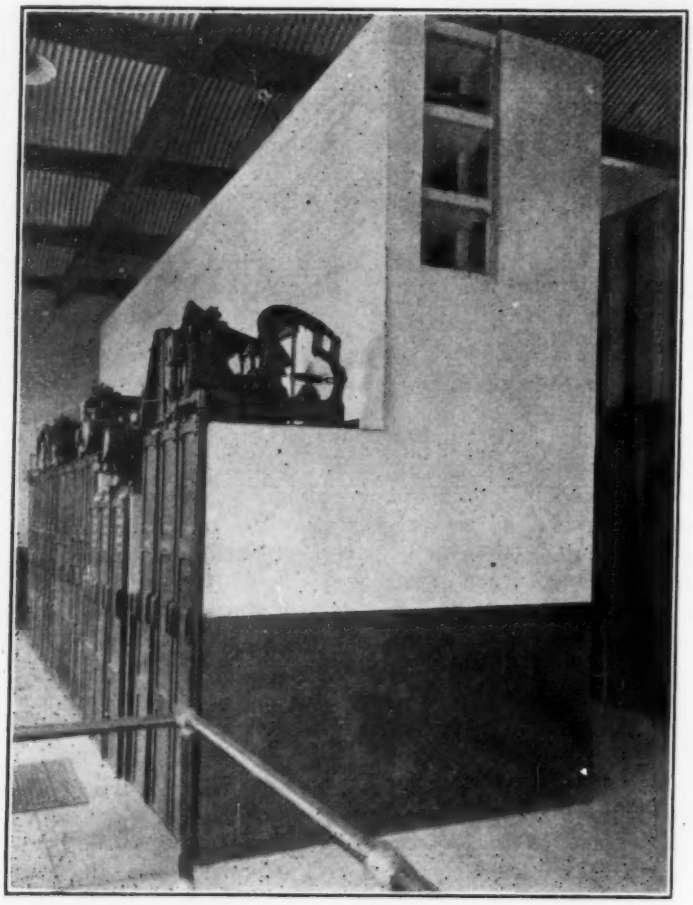


FIG. 7.

The 5,000-hp. 2200-volt 450-rpm. motor driving the continuous bar mill is supplied through three 500,000 cm circuits in parallel. The four 300-hp. cold roll motors have a 350,000 cm circuit and a similar circuit feeds the sheet mill sub-station. Another 350,000 cm cricuit supplies a bank of transformers in the sheet mill for operating 220-volt a.c. motors.

The Rod and Wire Mill Sub-tation is supplied with power through two circuits each consisting of two 350,000 cm circuits in parallel. This circuit carries about 3,500 kw. over a distance of 2200 ft. and is controlled by two 1,000-ampere oil circuit breakers at each end.

Mill Circuits.

Feeder circuits from sub-stations to mills are standard rubber covered wire on porcelain insulators. The 2200-volt circuits range from 600,000 cm to 4-0. The 250-volt d.c. circuits run from 1,000,000 cm to 250,000 cm carried on glass insulators. The direct current output of No. 1 Power Station is carried by two 1,000,000 cm wires in parallel to the Sheet Mill Sub-station and the Sheet Mill Sub-station and the Rod and Wire Mill Sub-station are tied in by a similar circuit. The 220-volt a.c. Rod Mill motors are supplied from the sub-station trnasformers by several circuits of 350,000 cm conductor.

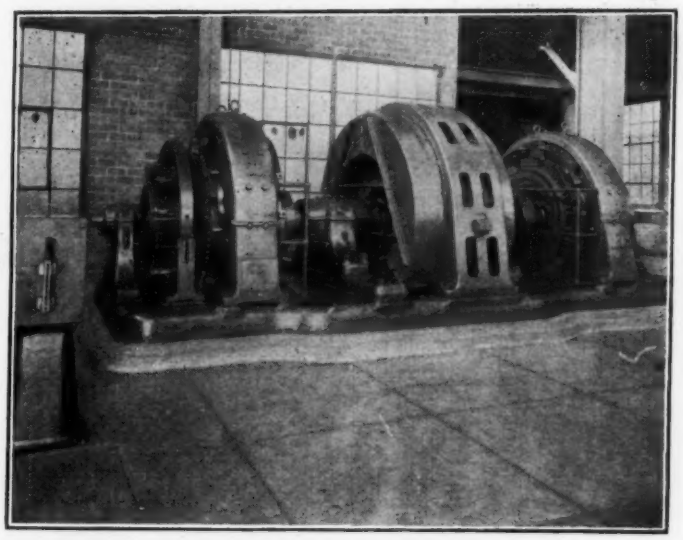
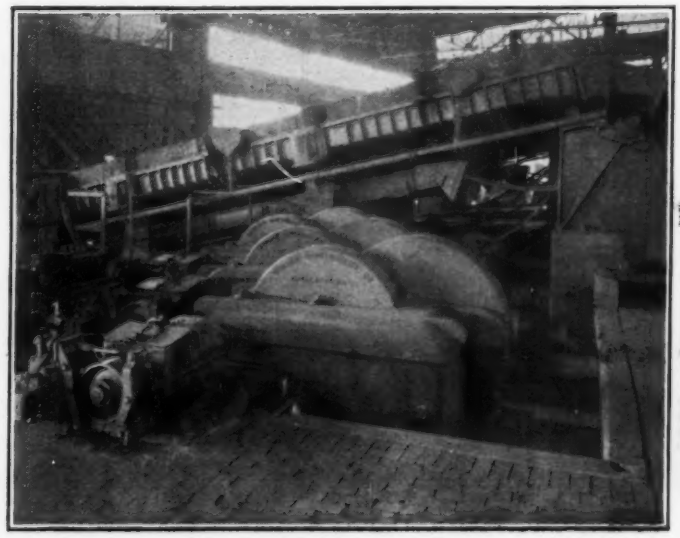


FIG. 8.

Pumping Station.

At the river bank abreast the blast furnace is located the concrete pump house with a capacity sufficient to supply a city of 300,000 people. From the grade entrance down to the pump room floor is about 60 ft. The pumps are below low water level and take water from three screened chambers along the river side wall.

Four 500-hp. 900-rpm. 2200-volt motors are direct connected through flexible couplings to four 14,000-g.p.m. 110-ft. head centrifugal pumps. Water passes to the plant through a 48 in. steel pipe line. A motor driven belted vacuum pump and a motor driven geared sump pump complete the equipment in this pump house. The compensators for controlling the pump motors are located on a gallery above the pumproom



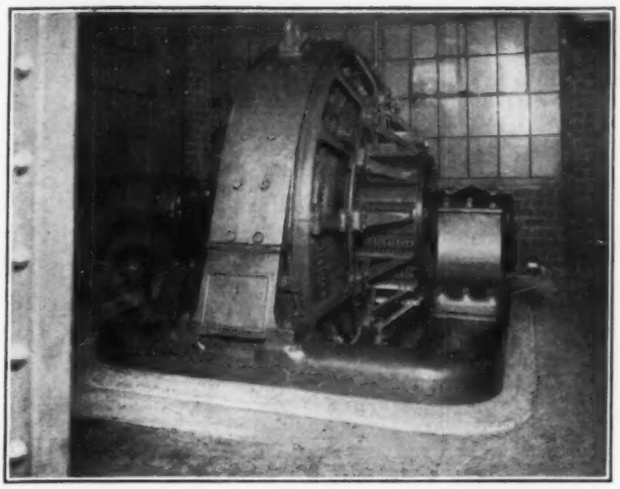


FIG. 9.

floor. About 35,000,000 gallons per day is required by the plant or 110 tons per ton of steel produced. Pumps and motors are lined up in Fig. 11 to be convenient for piping and maintenance work.

Control.

Magnetic control is general for motors throughout the plant. Manual control is used on cranes of 25-tons capacity and under. The 1,600-hp. Sheet Mill motor uses a liquid slip regulator for starting and for regulation to allow the motor to slow down so that the flywheel can take the heavy peak loads.

The 5,000-hp. motor on the 18 in. continuous mill is supplied with primary reversing oil circuit breakers and secondary magnetic control for starting and plugging duty, no speed regulation being required during running.

The adjustable speed Rod Mill motors of 2,870 hp. and 800 hp. on 600 volts d.c. take power from a bus and have magnetic control for starting and speed adjustment is obtained by motor shunt field regulation. Additional regulation below full field motor speed is obtained by lowering the bus voltage by generator field control. The fields of both the motors and generators are separately excited for this purpose.

FIG. 10.

Protection.

The principal power circuits are protected from lightning by oxide film arresters and sphere gaps at both ends of the lines. Multi-gap protection is provided for the lesser lines. The 11,000 volt and 2,300 volt circuits are provided with choke coils at each end of each line.

Direct current motors are protected by overload and under voltage attachments and automatic current limit acceleration.

Alternating current motors on 2,300 volt circuits are protected by devices in the following order: Lightning arrester, choke coils, disconnecting switches and oil circuit breakers.

Power Plant.

The line regulation on the entire system is exceptionally good due to the fact that it is possible to maintain

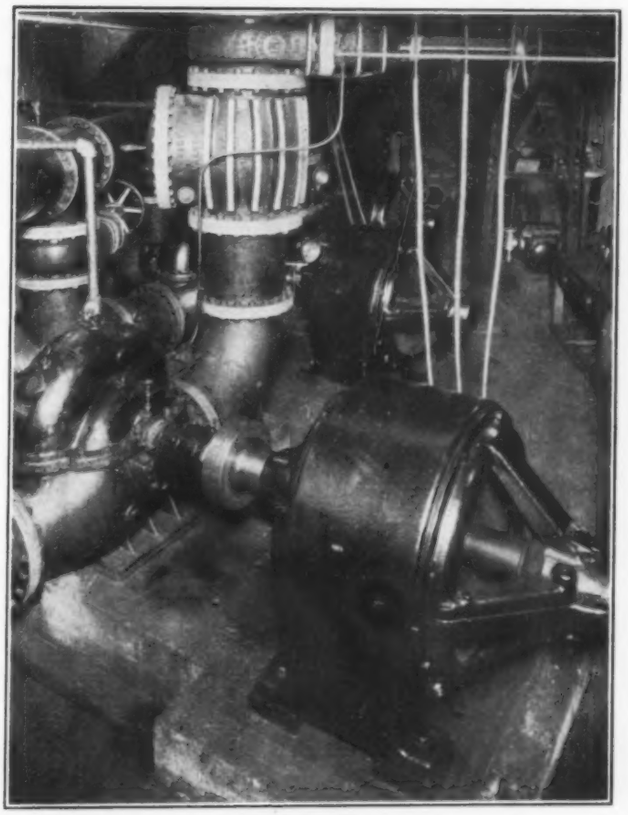


FIG. 11.

a .95 to unity power factor on all the transmission lines at all times. This is made possible by the large synchronous condenser capacity in the motors of the synchronous motor-generators in the various stations. This high power factor is taken advantage of by loading the 10,000-kw. .8-p.f. turbine generator to 12,500 kw. at unity power factor a change having been made in the turbine to enable it to carry this load.

Lighting.

Lighting load aggregates 600 kw. on a 125 volt a.c. system through lighting transformers.

Type C nitrogen filled lamps are used in 500 watt and 100 watt sizes.

Twenty-two inch frame enameled steel reflectors for overhead and eliptical angle reflectors for wall and column applications.

Notable Motor Applications.

BLAST FURNACE SECTION

	Motors	Horsepower
Ore bridge	11	665
Stock bins	9	240
Skip hoist	1 hoist	200
	3 crane	175
Ladle house crane	4	225
Pig casting machine motor		180

OPEN HEARTH FURNACES

	Motors	Horsepower
Three charging machines	5	552 per Mch.
Two 150-ton 4-girder ladle cranes	7	412 per crane
Two 150 ton screw operated ingot strippers	4	225 per Mch.
Three 7½-ton stock cranes	3	47 per crane
Scrap baler	1	60
Gas producer double hoist bucket cranes	4	105 per crane
Stokers	4	20 each
Coal elevators	2	15 "
Coal crushers	2	60 "
Skull cracker—90 ft. fixed hoist	2	120 "
Skull cracker—50 ft. traveling crane	4	217
Screw down	1	100
Reversing table	2	175 each
Intermediate table	4	60 "
Ingot buggy	1	150
Two 7½-ton soaking pit cranes	4	47 per crane
Thirty-ton crane	3	130 total
Fifteen-ton crane	3	75 "
Shear depressing table	3	60 each

24-INCH BAR MILL

Tables	25	30 each

18-INCH CONTINUOUS MILL

	Motors	Horsepower
Main roll drive	1	5000
Transfer tables and auxiliaries	15	30 each
Two 25-ton cranes	3	117 per crane

TIE PLATE DEPARTMENT

Six punches	1	20 each
Two 25-ton cranes	3 each	117 per crane
One 10-ton mine locomotive	2	50 each

JOBBING MILL

Screw down	2	20 each
Levellers	4	25 "
Conveyors	4	15 "
Picklers	2	15 each
Four 15-ton cranes — each	3	75 "

SHEET MILL, ANNEALING FURNACES AND WASHERS

	Motors	Horsepower
One hot roll motor		1600
Four cold roll motors		300 each
About 50 general service motors about		100

Two 50-ton cranes
One 40-ton crane
Three 20-ton cranes
Four 10-ton cranes
Two 7½-ton cranes
Two mono-rail cranes requiring in all 50 motors.
Four storage battery tractors for floor traffic.

BARREL DEPARTMENT

Fifty motors	10 each

RANGE, BOILER AND GALVANIZING DEPARTMENT

Two 10-ton cranes and miscellaneous machinery Two 5-ton cranes and miscellaneous machinery	50	10 each

RIVER DOCKS

	Motors	Horsepower
Coal handling crane	6	400
Crane for outgoing steel shipments	2	50
Larry car on coal dock	1	50
Belt coal conveyor	2	50 each
Coal crusher	1	5
Auxiliary pumping station	2 pump	200 each

ROD MILL

One roughing mill motor		2870/1435
Three intermediate and finishing stand motors		800/355 each
Ten service motors for conveyors, etc.		20 "
One 15-ton crane	3	25 "
Four service motors		25 "

WIRE MILL DRAWING DEPARTMENT

	Motors	Horsepower
Drawing machines	108	20 each
Twelve wire blocks	12	40 "
One 5-ton crane	3	40
Eighteen jib cranes	18	2½ "
Wire pickling	5	15 "
Fourteen block wire drawing bench	1	200
Two sets of small wire drawing machines	2	50 each

NAIL MILL

Four motors		50 each
Nail machines to shaft and beltings	2	30 "
Conveyors, bundlers, etc.	5	20 "
One 7½-ton crane	3	40

WIRE GALVANIZING DEPARTMENT

	Motors	Horsepower
Take up crane	2	50 each
One 3-unit motor-generator set		150
Five miscellaneous motors		15 each
One 5-ton crane	3	40

ELECTRO GALVANIZING DEPARTMENT

One electrolytic motor-generator set	15
One storage battery charging motor-generator set	

SHOPS

Carpenter shop	2	25 each
Cooper shop	2	15 "
Blacksmith shop	2	5 each
Machine shop	1	30
Machine shop	1	15
Electric repair shop	2	15 each

MISCELLANEOUS APPLICATIONS

One electric welding motor-generator set.
One motor-generator for 800 ft. of simplex contact larry car and tractor grounded system.

STORAGE BATTERIES

120-cell 200-ampere-hour battery No. 1 Power House.
Similar battery in metallurgical laboratory.
48-cell, 200-ampere-hour batteries on 12 tractors.
Storage batteries on engine stops for Sheet Mill and Jobbing Mill.

Electricity in the Pipe Foundry

By JAMES W. MOORE*

IT has been said that cast iron pipe is "pig iron with a hole in it." This may be true, just as the definition of a doughnut may be, nothing with something around it. However that might be, the process of putting the hole in the pig iron is one of many ramifications.

The processes described and facts given in this article pertain to operations of the American Cast Iron Pipe Company's plant located at Birmingham, Ala., which is one of the largest individual pipe foundries in the world in point of production. While different in some phases, and the magnitude of its operations, processes at this plant are fairly representative of prevailing conditions in most of the large pipe foundries in this country.

Thirteen hundred men are required to operate the plant, which operates 24 hours. The company does not operate a blast furnace, but if it did so it would require the entire output of two moderate sized furnaces, or the output from one of the largest type fur-

JAMES W. MOORE

naces to supply its 500-ton daily demand for pig iron. Sufficient material is handled to keep two average railroad trains, with full complement of crews and equipment, busy continuously, transporting raw materials into the plant and finished products to the markets of the world. A privately owned switch engine, with full complement of rolling stock, also three narrow gauge electric storage battery locomotives, and approximately 100 cars, are required to transfer and convey materials within the plant proper.

The company makes cast iron pipe and fittings in sizes 2 in. to 24 in. inclusive, and in addition to the main pipe foundries there are three fittings foundries and the necessary pattern and carpenter shops, machine shops, etc. Auxiliary to the manufacture of pipe is a gas producer plant, supplying approximately 6,000,000 cubic feet of 140 Btu. gas per day, for drying cores and molds, and a power plant substation from which 208 electric motors with a combined rating of 3,248 hp. are served. This plant also contains the 500-lb. pressure hydraulic pumps, which supply water

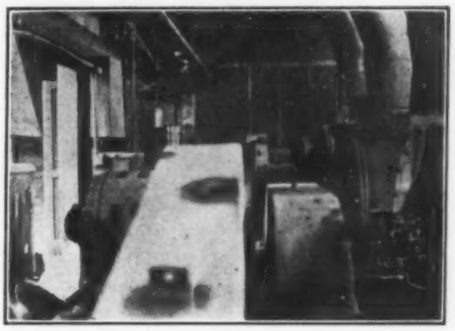


FIG. AA.

for test and power purposes, as well as direct driven air compressors. This equipment, however, will be described more fully later on.

Four cupolas operating alternately in pairs melt iron for the main pipe foundry, and three additional cupolas furnish molten metal for the fittings foundries. For every ton of iron melted approximately one ton of air must be blown into the cupola at approximately 1 lb. pressure. Standard equipment for doing this at Acipco (pronounced "a-sip-ko," and is the name of the plant and suburb where it is located) is a positive pressure blower, direct driven, through a silent chain drive, by a 50-hp., 900-rpm., 440-volt, 3-phase induction motor.

Molten iron from the cupolas is transported in 8,000-lb. ladles, on tram cars, to the various pipe pits. The hot metal trams are hauled by 5-ton, 36-in. gauge storage battery locomotives, which type and size are also standard for yard tram haulage. The storage battery locomotive at Acipco is an evolution of the

FIG. 1.

mule and steam dinkey locomotive. While figures are not at hand to show the savings effected by the steam dinkey over the mule, each "electric" has shown a saving of $2,500 per year, in round numbers, in operating expense over the steam dinkey locomotive. It is always on the job, reliable and powerful, costs

*Chief Engineer, American Cast Iron Pipe Company, Birmingham, Ala.

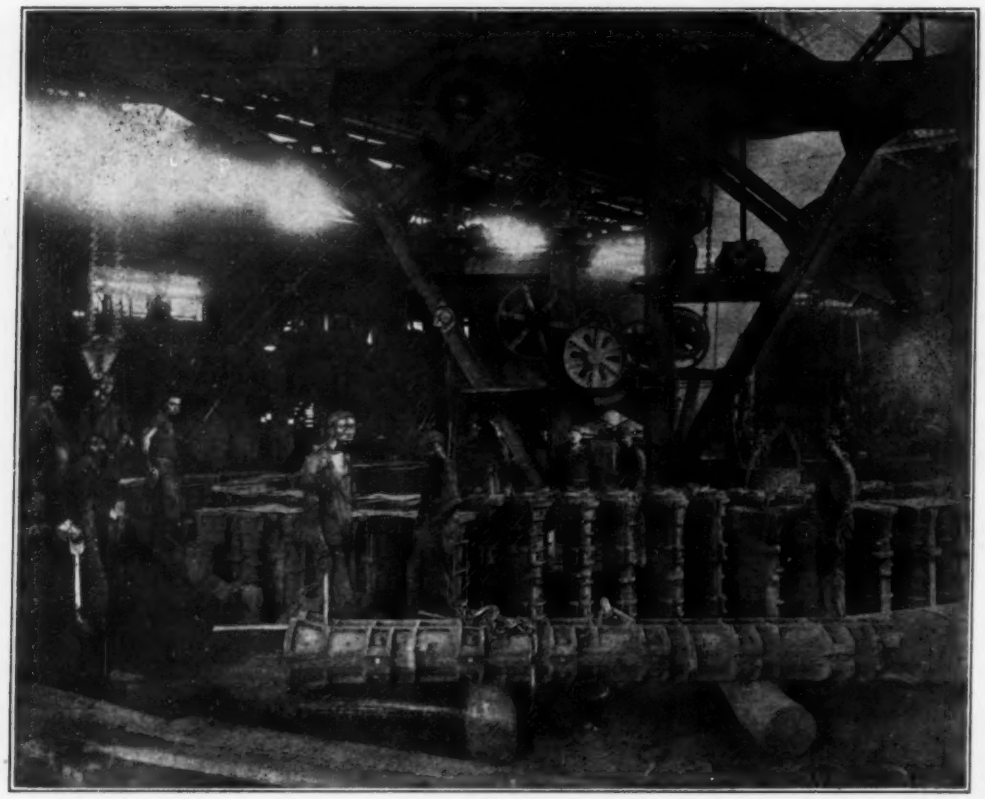


FIG. 2.

a nominal amount for repairs, and very little for maintenance. Power consumption with an average trailing load of 13½ tons and an average distance between start and stop of 230 feet is 15 kwh. for each locomotive, which makes 328 starts and stops and "does" about 70 ton-miles work per shift. After the day's work the locomotive has plenty of pep and reserve emergency capacity. Storage battery locomotive cost per ton mile at Acipco is 4½ cents, which includes cost of power, maintenance, repairs, and a liberal reserve for depreciation and interest on the investment.

Each pipe pit in the main foundry is served by a three-motor electric revolving jib crane. Steel mill operators think their service is the most severe, but that is perhaps because they do not know about the

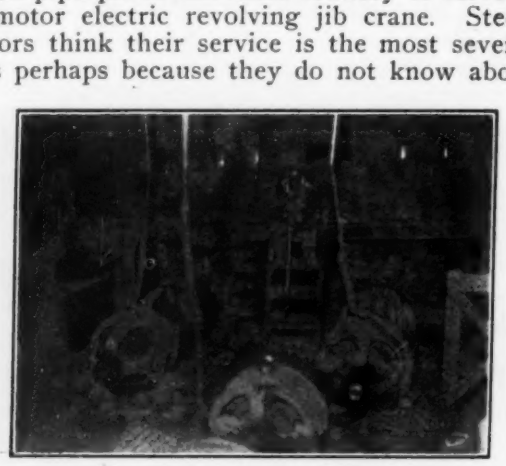


FIG. 3.

service of pipe shop jib crane motors. The crane motors are 230-volt d.c. series type, with dinkey controllers and "Q" brakes. Hoist motors are 30 hp. and 50 hp., swing motors are 30 hp., while 10 hp. is standard for the rack or trolley. Overhead three motor traveling cranes serve a rectangular pipe pit, the specialized, or fittings foundries, and machine shops. In all there are eight revolving jib cranes, ten overhead traveling cranes, and four steam locomotive cranes, with a combined capacity of 185 tons, all working to capacity in the interest of production.

The production of pipe is largely one of material handling. Over seven million pounds of equipment in the way of patterns, flasks, core bars, etc., is transferred, conveyed, or otherwise handled in getting out the day's work. For every ton of pipe produced and loaded in cars upwards of several hundred tons of equipment and material are handled, and the majority of this handling is done electrically. In one operation alone, that of ramming the molds, for each ton of pipe produced approximately 14 tons of equipment and material are raised and lowered, or jolted, 100 times, and it is done in less than two minutees. These rammers operate on the roller and cam principle. The cam shaft is driven by a 20-hp., 220-volt, d.c., 900-rpm., compound wound motor, direct connected to the jolt rammer, through a speed reducer and universal joint. Originally these units were provided with friction clutches between the motors and rammers, but these have been removed, and the practice now is to start the motor under load, through remote control push button stations and automatic starters. No motor troubles have resulted from this practice.

The problem of sand handling in the foundry is an important one. Part of the units at Acipco are served by a complete sand handling and conditioning plant, so that sand shaken out of the flasks when the pipe is made is conveyed back to the ramming station ready to be used over again. This plant includes reciprocating conveyors, flight conveyors and elevators, a revolving screen and heavy mixer. All of this equipment is motor driven, employing the 3-phase, 440-volt, 900-rpm. slip ring type, with drum controllers. The motor problem here is rather a serious one, on account of the dust and sand.

FIG. 4.

Pipe cores are made by pressing on and striking off mud or loam, applied to a steel or cast iron bar or arbor. This process is accomplished by revolving the arbor or bar in a pair of journals. The bars are revolved by electric motors, operating through clutch controlled speed changers, known as "core turners." These motors are at present 7½-hp., 220-volt, 850-rpm., compound wound, but are being replaced with 5-hp., 440-volt, 60-cycle, 900-rpm., squirrel cage induction motors. In fact, the policy now is to replace as rapidly as expedient all d.c. motors, except series crane motors, with the squirrel cage induction type. This will not only save transformation power losses, but greatly reduce repair costs.

For mixing and grinding the mud or loam for the cores, seven heavily constructed mud mills are required. Some of these operate singly, while others are driven in pairs, 25 hp. and 50 hp., 440-volt, 900-rpm., slip ring motors are employed for this service, driving the mills from a jack shaft with tight and loose pulleys. These motors replaced squirrel cage type, to avoid inconvenience in starting under load after power interruptions.

The special and green sand foundries where the pipe fittings are made employ electricity for its opera-

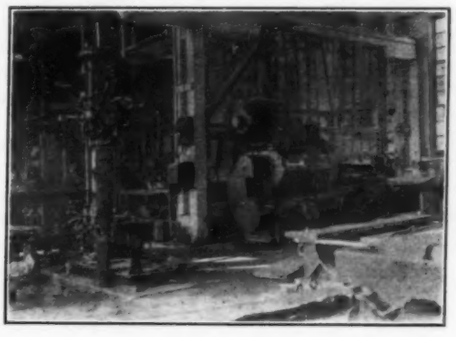


FIG. 5.

tion in the form of crane motors, etc. A comparatively new device, known as "standslinger," for machine molding of fittings and equipment, is a recent addition to Acipco special foundry. This machine is of the tractor type, that works its way into the sand heaps, elevates and screens the sand, throws it in small handfuls, so to speak, into the molds. The machine is a three-motor outfit, using 440-volt, 3-phase, squirrel cage type.

Machine shops and pattern shops at Acipco employ few, if any, novel devices or appliances. Though still maintaining the old line shaft and belted units, the tendency in recent years is toward direct motor driven machines, as evidenced in accompanying photographs.

It is not possible in a paper of this kind to enumerate and describe all classes of operations where electricity is playing its part; suffice it to say there are many other electrical devices such as circulating and fire pumps, tumbling barrels, fans, blowers, etc.

Summing up the power requirements, there are 120 d.c., 220-volt motors with a combined connected load of 1,980 hp.; 42 a.c., 440-volt, 3-phase motors, with a combined connected load of 907 hp., 225,000 watt connected light load, a total connected load including a few 110 and 220-volt, single-phase motors, heating units, etc., of 2800 kw. The maximum power demand is 865 kw., while the 24-hour consumption averages 14,000 kwh. The diversity factor is 31 per cent, and the load factor 70 per cent.

The matter of power is an important one, and recently the power plant at Acipco underwent radical changes and improvements, after a very careful and exhaustive study of operating conditions and costs. The old steam generating station was changed into an

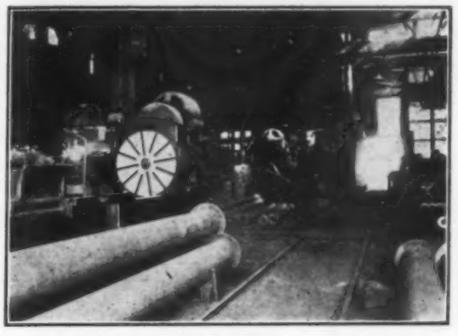


FIG. 6.

electric sub-station, suitable for operation from the lines of the local public utilities company, as it is operated at present, or from a steam generating station, should power rates or local conditions ever demand it. Four direct connected engine generator sets with total capacity of 525 kw., three steam driven hydraulic pumps, and one steam driven air compressor were replaced by three 200-kw., 2300-volt, a.c.-250-volt, d.c. motor generator sets, two 2300-volt motor driven 300-gallon, 500-lb. pressure hydraulic pumps, and two 625 cu. ft., 2300-volt synchronous motor direct driven air compressors. At the present time one pump and one compressor and two M-G sets carry the load, thus giving ample emergency reserve power. Eventually the station will be what might be called a "three-unit" station with three compressors, three pumps, and three M-G sets, two units carrying the load, with the third unit as spare equipment. Blank panels in the switchboard, conduits, and foundations for this expansion have been provided. To some, this might appear extravagant, but when it

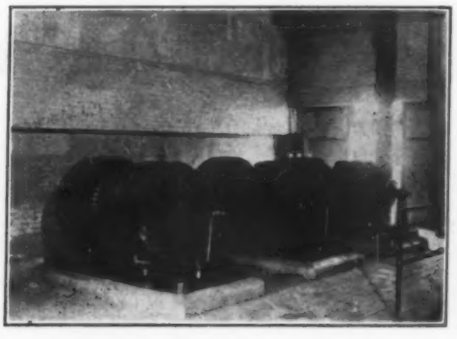


FIG. 7.

is realized what continuous operation means to pipe production it is found to be a good investment and very cheap insurance.

A 24-panel switchboard serves to control the power units enumerated above, and provide for additional equipment as the demand increases, and also takes

care of the 220-volt, d.c. and 440-volt, a.c. power feeders and 2300-volt lighting primaries. The switching equipment is of the remote mechanical control type, the oil circuit breakers, bus bars and 2300-440 transformer bank being located in a fireproof vault in the rear and six feet clear of the switchboard. Special consideration was given to the switching and control equipment to insure continuous operation and adequate metering of the current for the various departments and establishment of station losses. A graphic wattmeter, voltmeter, and power factor meter on the incoming line gives an accurate record of the service rendered by the utilities company and demand attachments are installed on all wattmeters. Daily log sheets showing the demands, consumption, voltage, and full operating data for each unit and department provide for very accurate and immediate control of the power situation, with attendant economies of operation.

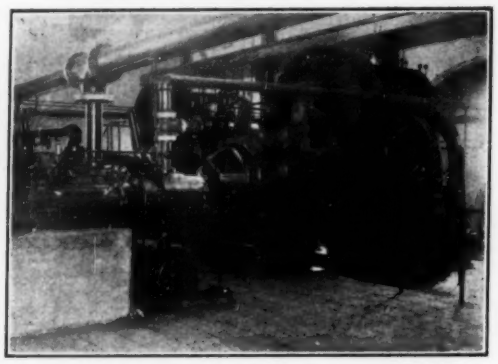


FIG. 8.

The new power station is showing an annual saving of approximately 30 per cent over the old steam station, and the service has been satisfactory in every respect. The new station has been in operation for a year, and so far there has been no loss to capacity due to interruptions of power. Although the new power station equipment was installed in the old station, the old equipment was removed and the new installed without any interruption to the service or loss of production capacity.

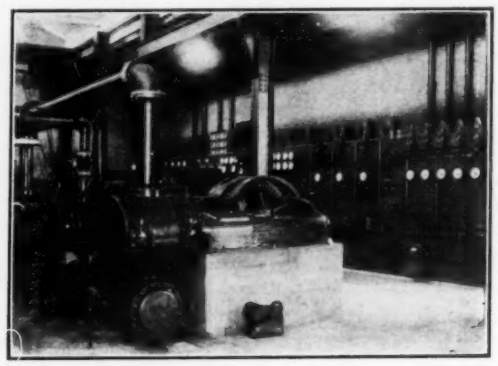


FIG. 9.

The tendency at Acipco, and it is believed to be general of foundries throughout the country, is toward greater and still greater use of electricity in its operations. Hence those following the electrical profession or interested in the wider application of electrical appliances will do well not to overlook this fertile field.

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Comparative Merit of Renewable Fuses

By ADDISON E. ARTHURS*

VERY often a prospective buyer is at sea as to how to fairly judge the merit of fuses. If you were asked the question, "How can I judge the merit of any fuses?" what would you answer? Certain it is that there must be some standard by which any fuse may be compared with another. The following is suggested as a workable standard of comparison, a "yard-stick":

Fundamentally, there are four angles of vital interest to the user of renewable fuses. These four angles are ever-present. Every user of fuses must be interested in all four of these. They are:

1—Safety.
2—Accuracy.
3—Utility.
4—Long life.

Safety.

Reliable makes of fuses in 250 and 600-volt and amperages up to 600 are fully approved by the Underwriters Laboratories. The "Und. Lab. Ins." label on a renewable fuse is a certificate of safety. The very severe short circuit tests to which such renewable fuses are subjected—10,000 amperes capacity—is an assurance of absolute safety under any and all service conditions. When you reflect that, at time of test, absorbent cotton is lightly packed around each fuse, so that the hot gases, if uncooled, will ignite it. If "cotton-firing" takes place the fuse is not approved. If the gases are so conducted away from the interior of the fuse as to be cooled when coming into contact with the cotton, then the cotton cannot be ignited or "fired."

Because such renewable fuses as bear the Underwriters' Laboratories labels have satisfactorily passed 10,000 ampere capacity ruptures, with each fuse enclosed in absorbent cotton, and because each size has done it five times to each casing, we know they are absolutely safe. The Underwriters' Laboratories also know it. The use of their approved label certifies the safety of such renewable fuses to the prospective user.

Accuracy.

By "accuracy" is meant the exact results the rating suggests. If fuses failed to carry rated currents it would result in premature expense and annoyance to the user. Accuracy also includes the need for blowing promptly at an overload. Failure to do this would cause alarmingly high repair bills, totaling many times the cost of a reliable accurate fuse. Fuses must carry a 10 per cent overload indefinitely. They must blow at a 50 per cent overload within the following time limits:

1- 30 ampere—	1 minute
31- 60 ampere—	2 minutes
61-100 ampere—	4 minutes
101-200 ampere—	6 minutes
201-400 ampere—	12 minutes
401-600 ampere—	15 minutes

The Underwriters' approval label certifies all this to you.

*Sales Engineer, Bussmann Manufacturing Company, St. Louis, Mo.

Utility.

Aside from the fact that the Underwriters' approval label assures the user that dimensionally such renewable fuses are "standard," i. e., they will exactly fit all approved cut-outs and clips, the approved label has no "use" significance.

Primarily the test of use is the ease and quickness with which a renewable fuse may be satisfactorily renewed and which contain fewer parts. Particularly is that true of the small, easily lost or misplaced parts. Secure samples of the various fuses which you have under consideration. Take them apart and put them together again. No matter how often you have done it, just do it again, to test them for one thing only—quick and easy renewal. Try all the fuses and you will quickly see the difference.

Long Life.

The problem of long life goes to the very heart of renewable fuse designing. Primarily the problem of effective design of renewable fuses is that of releasing enough pressure from inside of the fuse, at the time of blowing, to avoid injury to the case, and yet retain enough pressure to quickly quench the arc.

When the overload, whether light or heavy, causes the link to volatilize, the gases so brought into being are compressed inside the case. A high pressure immediately builds up. The venting of the fuse permits a partial escape. If the escape of these pent-up gases is too rapid, oxygen is introduced into the case, causing a prolonging of the arc. Such extended life of the arc causes excessive case pressure with resulting short life. Sometimes the arc is so prolonged as to weld the terminals of the zinc link to the retaining bolts. Then it cannot again be renewed.

So, effective venting is the true answer to long case life. Long case life means true savings.

A reliable venting system insures just enough pressure being released just enough pressure being retained to insure 100 per cent results every time. By holding down the pressure to the minimum required to effectually snuff out the arc, long case life is insured.

Fibre charring, or charring of the fibre at the ends of the tubes, is regarded by some users as a factor in long case life. But the user is directly responsible for any such damage to fuse cases.

Poor contact, with the resultant heat generated by electrical resistance, is the only and invariable cause of the burning or charring of fuses at the ends of the tubes. Such poor contact may be caused by:

Careless renewal of the fuse, not pulling the contacts up tight; not cleaning the contact points; permitting the renewal links to be exposed to the air to become oxidized or dirty.

Overloading the fuse, such as putting two 30-ampere links in a 30-ampere case.

Poor contact in the fuse block clips.

No renewable fuse is "fool-proof," but the prospective user should examine the fuses under consideration for features in design which tend to eliminate the possibility of making such poor contacts.

FUEL SAVING CONFERENCE

(Continued from Page 143)

Correction Factor — Quantity — Moisture, Superheat.

Correction Factor for Specific Gravity.

The subject of Air Preheaters was covered by B. G. Brolinson, Resident Engineer, A. B. Ljungstrom Angturbin, Stockholm, Chief Engineer, James Howden & Company of America, Inc., Wellsville, N. Y.

Engineer Brolinson divided his subject into eight parts as follows:

General Principals.
Method of heat transference.
Constructional details.
Air Preheater installations.
Comparison between economizers and air preheaters.
Furnace temperatures.
Application of the Ljungstrom Air Preheaters to steel mills.
Summary of advantages obtainable by the Ljungstrom Air Preheater.

One very interesting example of fuel saving was cited by the author in taking a case of a 1,000 h.p. boiler operated at about 280 per cent rating, burning blast furnace gas, with a heat value of 97 B.t.u. per cubic ft. using an air preheater. The temperature of the flue gases would be reduced from approximately 500 deg. F. to 226 deg. F., while the air temperature would be raised from 80 deg. F. to 396 deg. F., resulting in a saving in fuel of about 12 per cent.

This saving evaluated in coal of 11,500 B.t.u. at $5.00 per ton would probably amount to about $25,000 per year, depending of course, on the load factor on the boiler.

On a 400 h.p. Stirling boiler, operated at 200 per cent rating, a C-12 air preheater would be required. The waste gases are entering the preheater at a temperature of 750 deg. F. heating the air to approximately 580 deg. F., corresponding to a saving of about 17.5 per cent in fuel.

Under a summary of advantages obtainable by the use of an air preheater the author makes the following claims:

Greatly increased boiler efficiency — Saving in operating costs.

Ratings of boilers increased to the maximum — Saving in capital investment.

Possibility of operating boilers at high ratings with low grade fuel — Saving in fuel costs.

Mr. Wm. C. Buell, Jr., with the Chapman Stein Furnace Company, Mt. Vernon, Ohio, presented a paper covering the Chapman Stein Recuperator. Mr. Buell's discussion related to the following topics:

Basic principals.
Recuperator design of Charles M. Stein.
Furnace operation.
Economies of the Chapman Stein Recuperator.
Installations.

Engineer Buell exemplified his paper with the use of about 20 illustrations. The author's summary was as follows:

In a little over three years, and working against the normal American prejudice against any device of European origin used in productive practice, and in the face of post war slump, we have made some 60 recuperator installations, all of which designed and installed by the licensees are still in daily use and none of which to this date have been repaired, or so far as we know, required repairs. We have standard recuperators working which are receiving fumes at temperatures as high as 2500 deg. F. and delivering the air at temperatures in excess of 2000 deg. F. and it is believed that with the refractory material as used, the Chapman-Stein Recuperator is capable of receiving fumes at temperatures as high as 3000 deg. F., operating indefinitely at this temperature.

Of the three installations which will be described, the first has been in use over two years and been subject to at least 100 cold shut-downs, and the users state that they cannot see that the recuperator is changed in any regard. In fact, the output has increased. The installation of two furnaces is at the Youngstown Sheet & Tube Company on a 14-in. skelp mill. These furnaces are each 11 ft. in width and about 28 ft. heating length. They were designed to deliver 12 tons of slabs per hour each, and to replace three furnaces of the continuous regenerative type. At the normal production of 12 tons per hour each, they are credited with having produced this tonnage of slabs on a consumption of about 169 lbs. of coal in the producer per ton of metal heated. However, as a greater tonnage of skelp could be rolled, the furnaces for 18 months have been delivering 20 tons per hour each and coal consumption has jumped to about 220 lbs.

Due to the fact that, owing to the greater volume of gases handled, velocities have increased materially and the recuperator has been unable to return the percentage of heat of which it is capable at the lower rate. This is shown in air temperatures which, at the smaller capacities, was 1,450 deg. F., and at the higher capacities, is only 1,150 deg. F. That these furnaces have been able to deliver this large tonnage at the relative low fuel figure, has been due to the fact that it is possible to run the furnaces hot throughout their length and salvage the considerable amount of heat entering the down-takes to the recuperators and return a large proportion of this in the heated air.

Dr. F. W. Davis, Bureau of Mines, Washington, D. C., presented an intensely interesting paper covering the subject of "Some Applications of Oxygen to Ferrous Metallurgy." He said in part:

The application of oxygen to metallurgical fields has received more or less discussion for several years. The high cost of oxygen, however, has prevented any great amount of work being done along this line. In view of recent developments in gas separation, together with the increasing cost and decreasing supply of raw materials, the U. S. Bureau of Mines has undertaken the problem of the manufacture and application of cheap oxygen to metallurgical purposes. The Advisory Committee to the bureau on this problem have reported that oxygen may now be produced in large quantities at a cost sufficiently low as to make the application to certain processes commercially attractive.

From the metallurgical studies it has been concluded that the use of an oxygenated air blast in the iron blast furnace will give the operator a more direct control over the operation of the furnace, increase the uniformity of the process, permit of cheaper raw materials being used and at the same time increase the furnace output and lower production costs.

It is proposed to use oxygen in the manufacture of Bessemer steel. If the oxygen in the blast of a Bessemer converter may be increased or decreased at will, the requirements for pig iron for this process may be greatly lowered. In the basic Bessemer process, the greater portion of the necessary heat is generated by the oxidation of phosphorus. None of our American iron ores have sufficient phosphorus to produce a basic Bessemer pig iron. With the use of oxygen enriched blast however, we will lower the heat requirements to such an extent as to make possible the Bessemerizing of the pig from the so called intermediate phosphorus ores. Thus making possible the establishment of a basic Bessemer industry to utilize material which has heretofore been more or less unsatisfactory.

It is estimated that the time requirements of the open hearth process may be decreased about one-third by the use of oxygen. It is proposed to substitute this gas as an oxidizing agent in place of the iron ore now used. Further, it is proposed by partial combustion of the gas to finish the steel under reducing conditions. The high temperature reducing flame to be maintained by the partial combustion of fuel gas with pure oxygen.

There appear to be many applications of oxygen in fuel lines, such as the manufacture of a high calorific producer gas, the combustion of blast furnace gas, and the utilization of other low grade fuels such as coke breeze, lignite, etc.

The production of ferro-alloys is a field in which cheap oxygen offers particular promise. The high temperature repuirements for reduction in these processes render ordinary blast furnace production either very inefficient or else impossible. With a blast available in which the oxygen may be increased at will, the high temperature heat may be increased to such an extent as to effect great economies in processes such as the manufacture of ferro-manganese, ferro-chromium, and ferro-silicon. It is believed further that other alloys now requiring electric furnace reduction will be manufactured in the coke furnace with oxygen enriched blast.

Dr. R. E. Hall, Bureau of Mines, Pittsburgh, Pa., assisted by Carl Fischer, Power Engineer, Mesta Machine Company and Mr. G. W. Smith, of the Hagan Corporation presented an intensely interesting paper covering the subject of "Prevention of Scale Formation by Boiler Water Conditioning."

The first part of the paper dealt with the principles of water and steam conditioning. The second part the application of these principles in a plant test. The first part of the paper dealt with the divisions of water conditioning, sludge removal, and the production of dry steam.

In conditioning water a distinct division must be made between the process which makes the deposition and growth of hard adherent scale impossible and the removal of the sludge which is produced in this process. The first is distinctly a chemical problem; the second entirely mechanical.

In order to ensure a condition such that hard adherent scale will not form, it is essential that the equilibria existing in the boiler water itself be controlled in place of treating the feed water and allowing the boiler water conditions to take care of themselves. Curves were shown tabulating the conditions which must exist in the boiler in order to attain this condition. Curves were shown relative to the disposition of the sludge by a filtration of the feed water or by a filtration of part of the boiler water at boiler temperature and pressure. The protection of the steam from water carried over from the boiler was discussed.

The plant test had been running for 134 days. The condition in which the boiler water was maintained was shown. The condition of the tubes in this boiler and in one along side using no treatment, was also demonstrated. In this test the removal of the sludge resulting from treatment was accomplished by means of the Hagan deconcentrator. All operating figures were shown. There has been no tube loss whatever on this boiler since the inception of treatment November 20, 1923.

Mr. W. P. Chandler, Jr., Fuel and Combustion Engineer, Carnegie Steel Company, Duquesne, Pa., discussed the Control of Pressure Gas Producers. He divided his subject into the following topics:

Description of Pressure Gas Producers.
Gasification rate.
Gasification efficiency.
Fusibility of ash.
Fusibility of coal ash.
Control of combustion zone temperature.
Producer operation.

The author summarized his article as follows:

The large amounts of coal consumed in gas producers in steel mills, requires that equipment be installed which will enable the operator to exercise the same careful control of operation, which is expected at present in boiler houses.

Care must be exercised to see that the charging is as regular as the type of equipment will permit, and that the ashes are removed without excessive breaking up of fuel bed, or excessive loss of unconsumed carbon.

A gas producer can be intelligently controlled only when the blast temperature is known, and means are provided for altering this temperature, so as to provide the amount of moisture demanded by the character of the coal being used. Such a requirement can be met only by a separate supply of air and moisture, such as is available when turbo-blowers are used, and auxiliary means provided for wasting part of the exhaust steam, or furnishing additional amounts of live steam as conditions demand.

Experience has shown that the steam jet blower, which has a maximum efficiency for only one grade of coal, is not sufficiently flexible in its operation to meet the various grades of coal usually handled by gas producers; and, that maximum efficiency can be obtained only through the separate control of air and moisture available from the installation of turbo-blowers.

A list of the engineers who participated in the conference and discussions are:

J. H. Albrecht, D. Connelly Boiler Co., 711 Empirt Bldg., Pittsburgh, Pa.
F. C. Andresen, President, "Fuels and Furnaces," Pittsburgh, Pa.
D. P. Anderson, Chief Draftsman, Duquesne Works, Carnegie Steel Co., Duquesne, Pa.
C. E. Angustine, Asst. Fuel Engr., U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.
H. Bacharach, President, Bacharach Industrial Instrument Co., Pittsburgh, Pa.
Phillips Badenhausen, Badenhausen Company, Philadelphia, Pa.
Edward Ball, Student, Carnegie Tech, 1423 Carnegie Avenue, McKeesport, Pa.
B. J. Ballard, Mgr., Reliance Elec & Engr. Co., Pittsburgh, Pa.
F. C. Binnall, Comb. Engr., Standard Sanitary Mfg. Co., Bessemer Bldg., Pittsburgh, Pa.

A. E. Blake, Pgh. Rep., The U. G. I. Cont. Co., 238 Union Trust Bldg., Pittsburgh, Pa.
F. E. Bloom, Gas Producer Supt., J. & L. Steel Corporation, S. S. Works, Pittsburgh, Pa.
H. A. Bowley, Sales Engr., Republic Flow Meter Co., 1411 Union National Bank Bldg., Pittsburgh, Pa.
Grant Bradshaw, President, Andrews Bradshaw Company, 530 Fourth Avenue, Pittsburgh, Pa.
F. J. Brittingham, Mgr., Cleveland Crane & Eng. Co., Pittsburgh, Pa.
B. G. Brolinson, Engineer, James Howden & Co., Wellsville, N. Y.
E. Brosius, Bailey Meter Company, Pittsburgh, Pa.
W. P. Brown, Chief Chemist, Carnegie Steel Co., Duquesne, Pa.
W. C. Buell, Jr., Chapman Stein Furnace Co., Mt. Vernon, Ohio.
Fred H. Butterfield, Chief Engr., Laclede Steel Co., St. Louis, Mo.
George L. Buggemeier, Student C. T., 4921 Forbes St., Pittsburgh, Pa.
E. W. Campion, Asst. Supt. Buckeye Steel Castings Co., Columbus, Ohio.
W. P. Chandler, Fuel Engineer, Carnegie Steel Co., Duquesne, Pa.
A. A. Claasen, Chief Engineer, Interstate Steel Co., Chicago, Ill.
J. W. Clark, Valley Mould & Iron Corp., Sharpsville. Pa.
Elmer C. Cook, Editor, Fuels & Furnaces, House Bldg., Pittsburgh, Pa.
A. L. Cole, Assoc. Editor "Power", McGraw Hill Co., Inc., New York, N. Y.
Chas. J. Colgan, West Penn Power Co., P. O. Box 1223, Pittsburgh, Pa.
Geo. D. Conlee, Mech. Engr., Republic Flow Meters Co., Chicago, Ill.
Martin J. Conway, Fuel Engr., Wheeling Steel Corporation, Steubenville, Ohio.
H. R. Cornelius, Sales Engr., Mest Machine Co., Oliver Bldg., Pittsburgh, Pa.
F. Crabtree, Professor, Carnegie Institute of Technology, Pittsburgh, Pa.
Frank W. Cramer, Asst. to Elec. Engr., Bethlehem Steel Co., Johnstown, Pa.
J. B. Crane, Engineer, Geo. T. Ladd Company, Pittsburgh, Pa.
Robert Crookston, Student, Carnegie Tech, 152 Fifth St., Irvin, Pa.
A. L. Culbertson, Mgr., Chapman Stein Furnace Co., Mt. Vernon, Ohio.
W. R. Culbertson, Chapman Stein Furnace Co., Mt. Vernon, Ohio.
A. C. Cummins, E. E., Carnegie Steel Co., Duquesne, Pa.
W. C. Curtin, Student, C. T., 1655 Shady Avenue, Pittsburgh, Pa.
F. G. Cutler, Chief Bureau of Steam Engrg., Tennessee Coal, Iron and Railroad Company, Ensley, Ala.
Hugh D. McDavell, Engineer, West Penn Power Co., Wood St., Pittsburgh, Pa.
C. W. Daubert, Steam Engr. Dept., American Sheet & Tin Plate Co., Pittsburgh, Pa.
N. L. Daney, Treasurer, The Chapman Stein Furnace Co., Mt. Vernon, Ohio.
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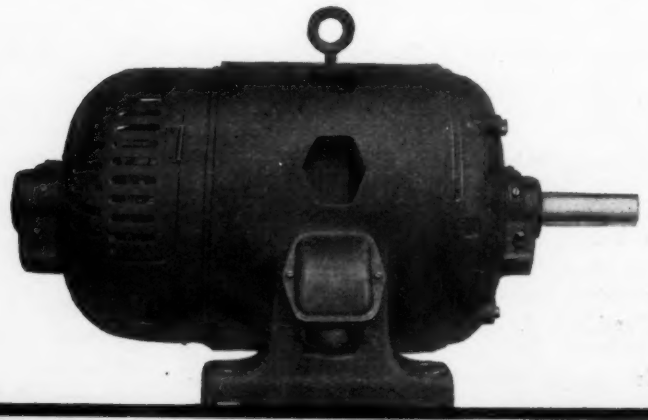

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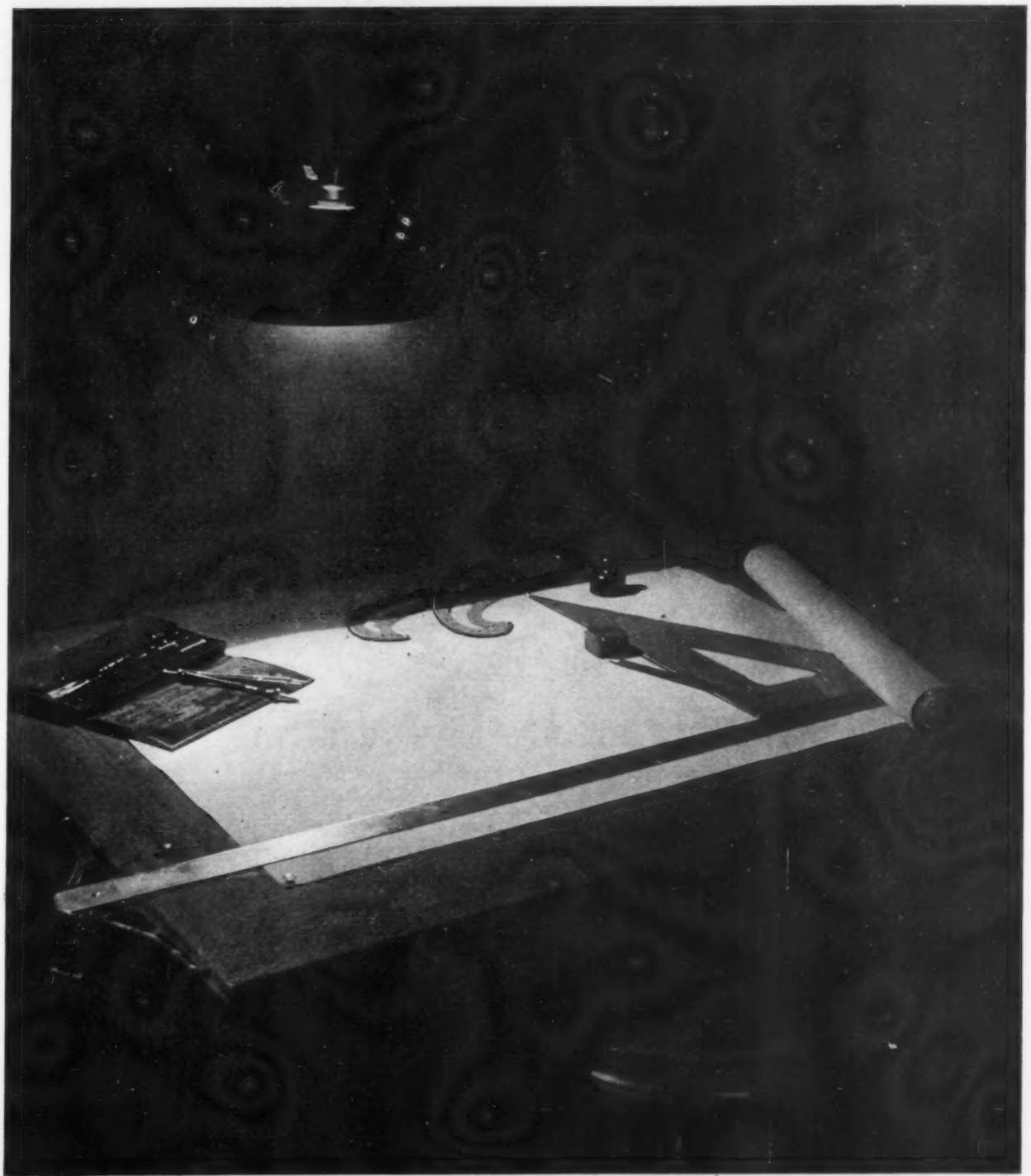

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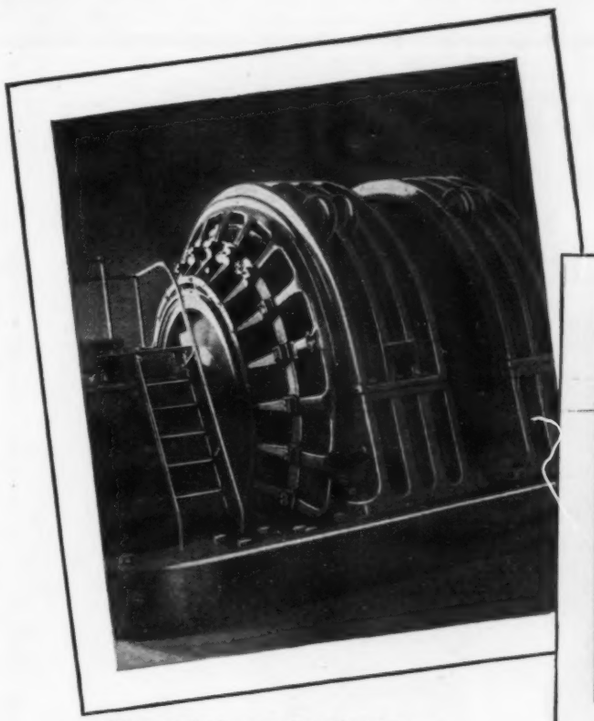

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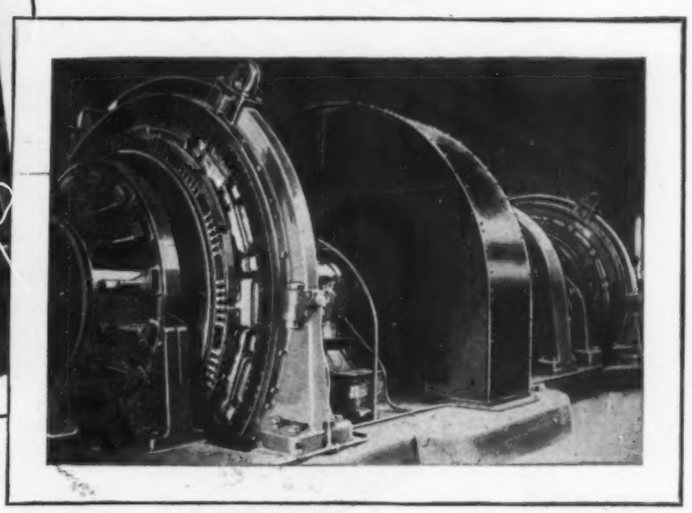

Generator in Trumbull blooming mill, rated 3334 amperes but delivering more than three times that current at peak load. Here, National Pyramid Brushes are giving exceptional service.

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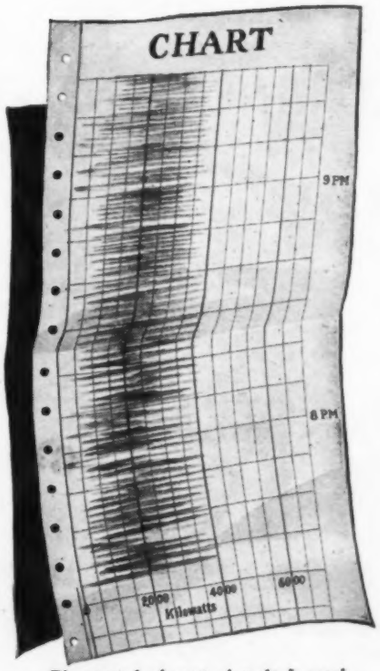

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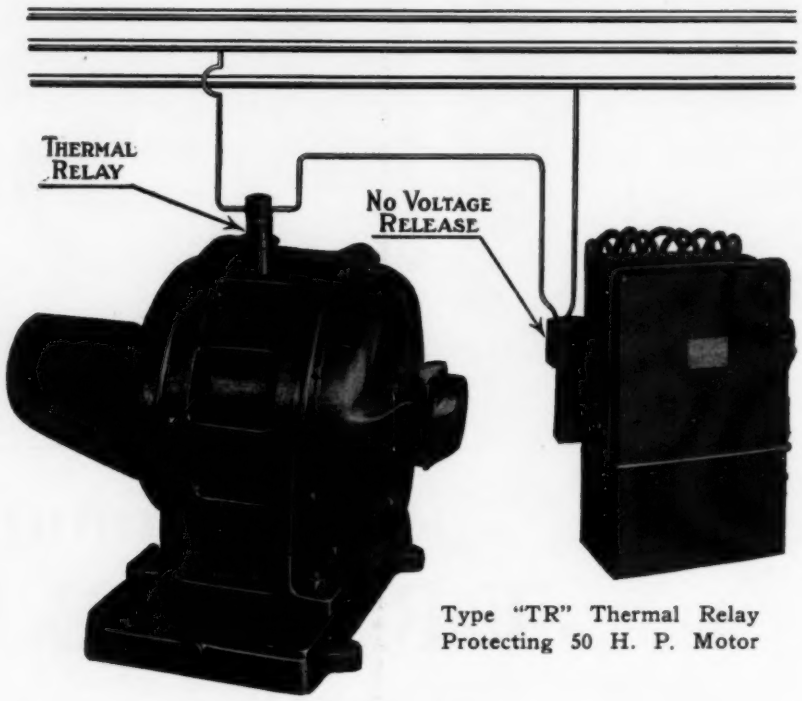
MOTOR PROTECTION BASED ON MOTOR TEMPERATURE IS CORRECT



Type "TR" Thermal Relay Protecting 50 H. P. Motor

IT IS ALSO

SIMPLE - EFFECTIVE - RELIABLE - INEXPENSIVE

AND

EASY TO INSTALL

A TYPE "TR" THERMAL RELAY TO PROTECT THE RUNNING MOTOR } AGAINST { 1—Roasting out; 2—Phase Failure; 3—Continuous Overload; 4—Mechanical Friction; 5—Worn out Bearings; 6—Rotor Dragging on Stator } + { OVERLOAD RELAYS OR FUSES TO PROTECT THE STALLED MOTOR

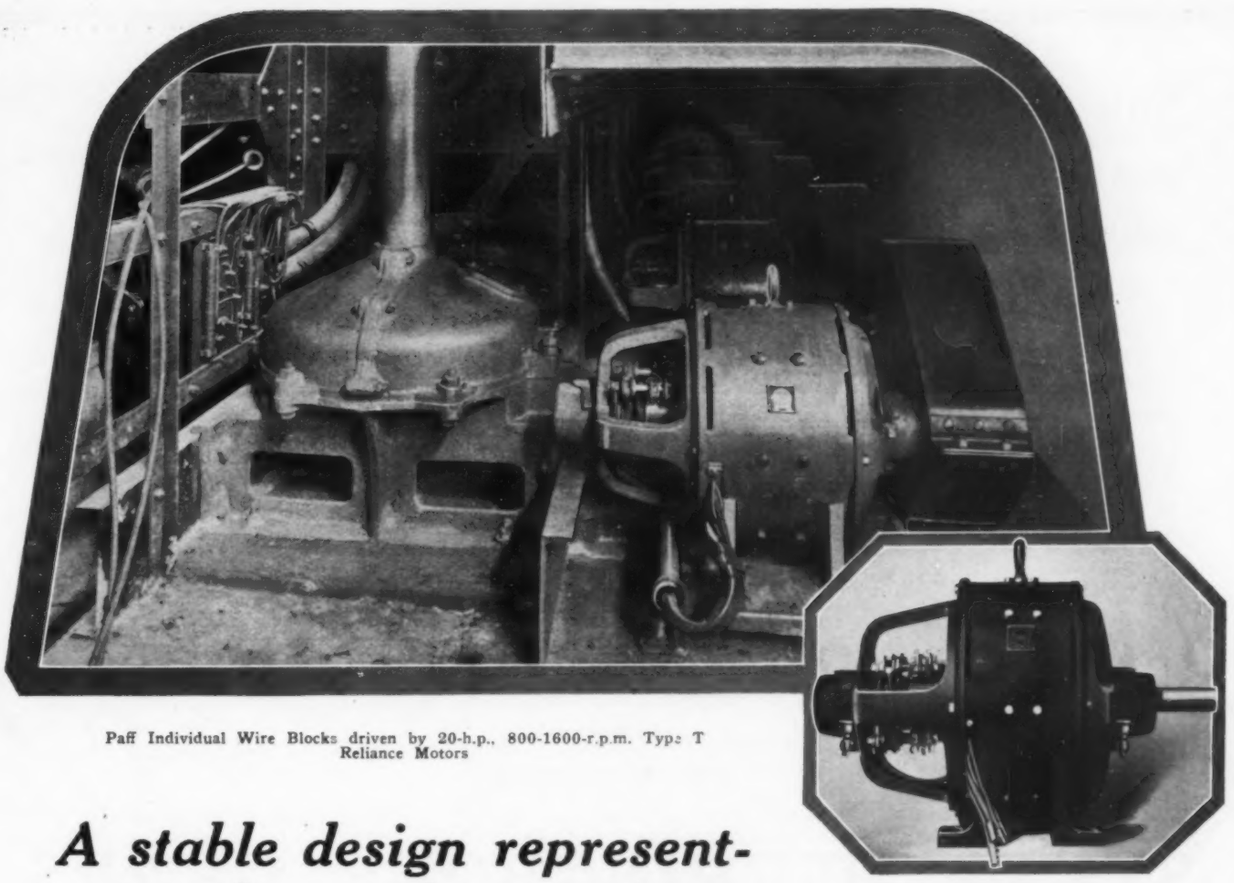
And you have COMPLETE and RELIABLE MOTOR PROTECTION at a very low cost.

Bulletin 402-F Gives Details.

THE AUTOMATIC RECLOSING CIRCUIT BREAKER CO.

COLUMBUS, OHIO

PITTSBURGH: 223 Oliver Bldg.
ST. LOUIS: 401 National Bank of Commerce Bldg.
WILKES-BARRE, PA.: 816 Miners Bank Bldg.
CHARLESTON, W. VA.: 317-318 Moore Bldg.



Paff Individual Wire Blocks driven by 20-h.p., 800-1600-r.p.m. Type T Reliance Motors

A stable design representing the user's experience

Frequent design changes make spare part stocks burdensome and replacements difficult. Recognizing this we offered Type T Reliance Motors to steel mill engineers as a stable design embodying their ideas of a truly heavy-duty general-purpose motor. In eight years no change has been made which affects interchangeability and none is anticipated.

Eight years of hard service have demonstrated the wisdom of getting more of the user's experience into motor design. Type T motors in installations of 1 to 1700 have been doing the hard jobs and doing them well. We shall be glad to submit complete evidence.

You can easily get the whole story of Type T motors from our Bulletin 2014. It contains 77 illustrations showing just how the motors are made and applied to a variety of work.

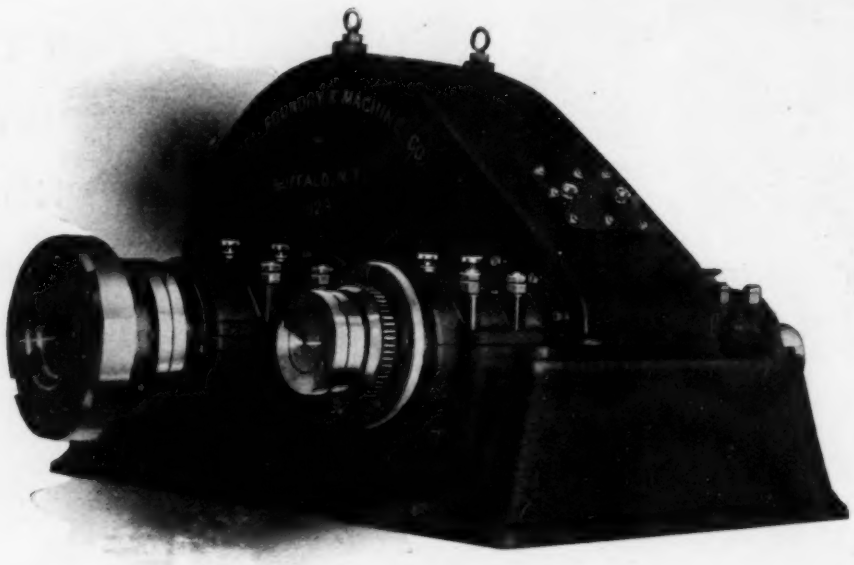
Steel mill electrical engineers who co-operated with us in the design of Type T motors have learned from practical experience in their repair shops where extra quality and strength would mean better motor service. It was such experience that guided us in the building of a motor that would stay on the job longer and be in the repair shop less.

Reliance Electric & Engineering Company

1080 Ivanhoe Road, Cleveland, O.

Branches: Boston, New York, Philadelphia, Pittsburgh, Cincinnati, Detroit, Chicago

Type T Heavy Duty RELIANCE MOTORS- Direct Current

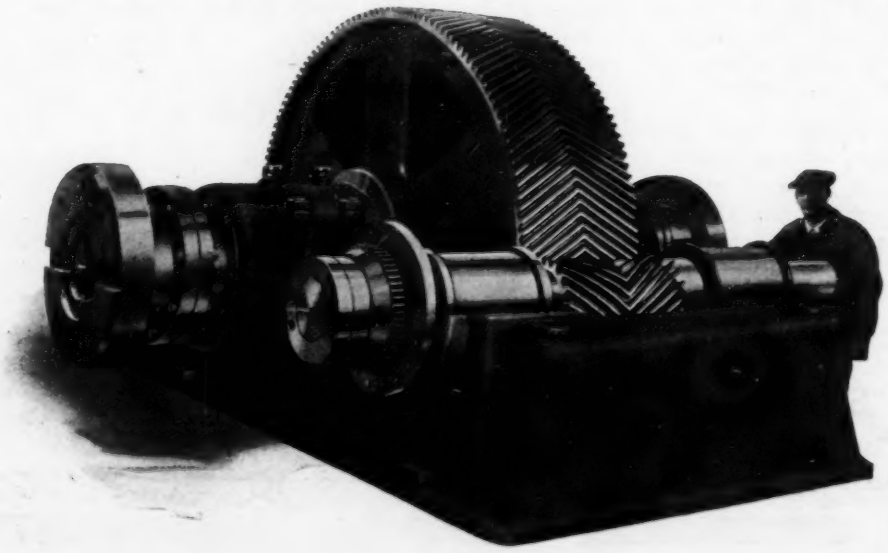


FARREL ROLLING MILL DRIVE

THE STRONGEST — MOST COMPACT AND EFFICIENT DRIVE
ON THE MARKET

SYKES HERRINGBONE GEARS

NO GAP AT THE CENTER—SHARP APICES



FARREL FOUNDRY & MACHINE CO., Inc.

BUFFALO, N. Y., U. S. A.

"We can cut our fuse consumption 50% by using your product"

RADIO THE HOT WATER RADIATOR WITH THE OPEN FIRE PLACE FOR THE HOUSE WITHOUT A CELLAR— HOT WATER HEAT IN EVERY ROOM

CENTRAL RADIATOR COMPANY

LANSDALE, PA.

RADEX SELF-FEEDING STEAM AND WATER BOILERS FOR THE SMALL HOUSE DOWN DRAFT MORE-CONSUMING —AT A POPULAR PRICE

January 15, 1924.

Bussmann Mfg. Company,
St. Louis, Mo.

Gentlemen:

We have recently signed a contract to use the Buss Fuses exclusively at our Plant for the year 1924. Our reason for doing this was due to the fact that during the past year we procured a quantity of these fuses from our Electric Light Commission, Lansdale, and found them so much more serviceable and satisfactory, both to the quick renewal and the long life of the fuses, and we are under the impression that we can cut our fuse consumption 50% by using your product.

We trust that you will arrange with your local representative to have a full line of your fuses in stock at all times so that they can be procured in the quantities as desired by us.

Very truly yours,

CENTRAL RADIATOR COMPANY.

HFQ:SC

MANAGER.

Poor contact is the chief cause of fuse destruction.

In the BUSS Renewable Fuse the extreme simplicity of design not only permits quick, easy renewal, but prevents poor contact due to faulty renewal.

INSERT THE LINK
closed end eliminates one washer
PUT ON CAP
full length cap gives large gripping surface
SLIP WASHER ON
washer is held by bent end of link
PUT ON SECOND CAP
(note projection and recess)
and
THE FUSE IS READY FOR SERVICE

A sample will convince you

BUSS FUSES

APPROVED IN ALL TYPES AND SIZES

TRADE Buss Fuses ELECTRICITY'S SAFETY VALVE MARK REG. U.S. PAT. OFF.

"ELECTRICITY'S SAFETY VALVE" MEANS OUR

BUSSMANN MANUFACTURING CO.
3819 No. Twenty-Third St., St. Louis, Mo.
Without obligation, send me for examination sample 30 ampere, 250 volt Ferrule Contact Type BUSS Renewable Fuse.

I-SW 4-24

Name _____ Position _____
Company _____
Street _____
City _____ State _____

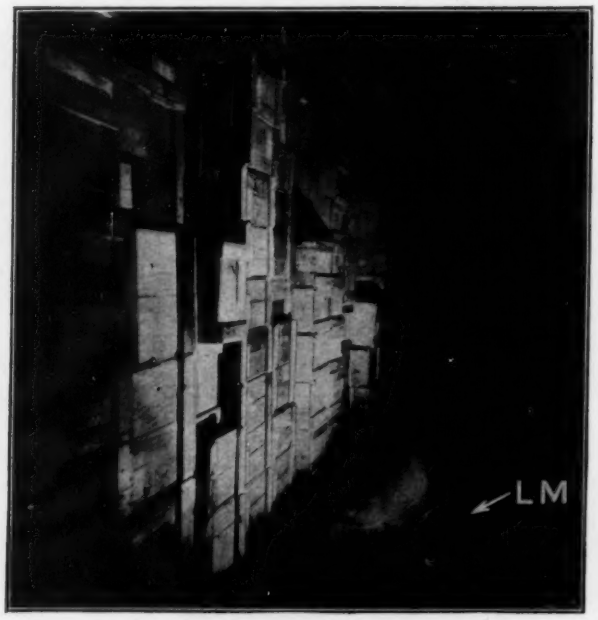
HAND LANTERNS

TYPE LM

Puts the Light Where You Want It

Type LM Lantern

Type LM is a convenient, portable inspection lantern for use in Railway Coach Yards, Roundhouses, Shops, Transfer Terminals, Garages, Weaving Mills, or where a strong, well protected light is needed.



Storehouse—LM Installation

The body is cast aluminum and has a friction adjustment so that the light can be directed up or down. A cast iron base gives a substantial support.

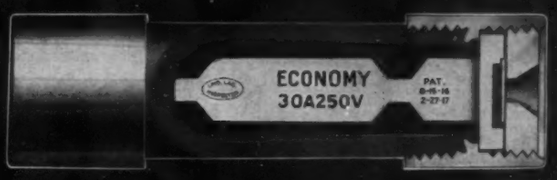
Write for further information.

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

SALES OFFICES
NEW YORK BOSTON CHICAGO
PHILADELPHIA DETROIT ST. LOUIS MINNEAPOLIS
CINCINNATI SAN FRANCISCO

CH 119

CROUSE-HINDS



INDUSTRIES using electrical energy save 80% annually in fuse maintenance costs by installing Economy Renewable Fuses in the place of "one-time" fuses.

The famous Economy "Drop Out" Renewal Link—the least expensive and the only portion of the fuse destroyed in operation—makes this saving possible.

Check up your fuse costs.

For Sale by All Leading Electrical Jobbers and Dealers

ECONOMY FUSE & MFG. COMPANY
Chicago, U. S. A.

Economy Fuses were the first line using an inexpensive bare renewal link for restoring a blown fuse to its original efficency to be Approved in All Capacities by the Underwriters' Laboratories.

ECONOMY *renewable* FUSES

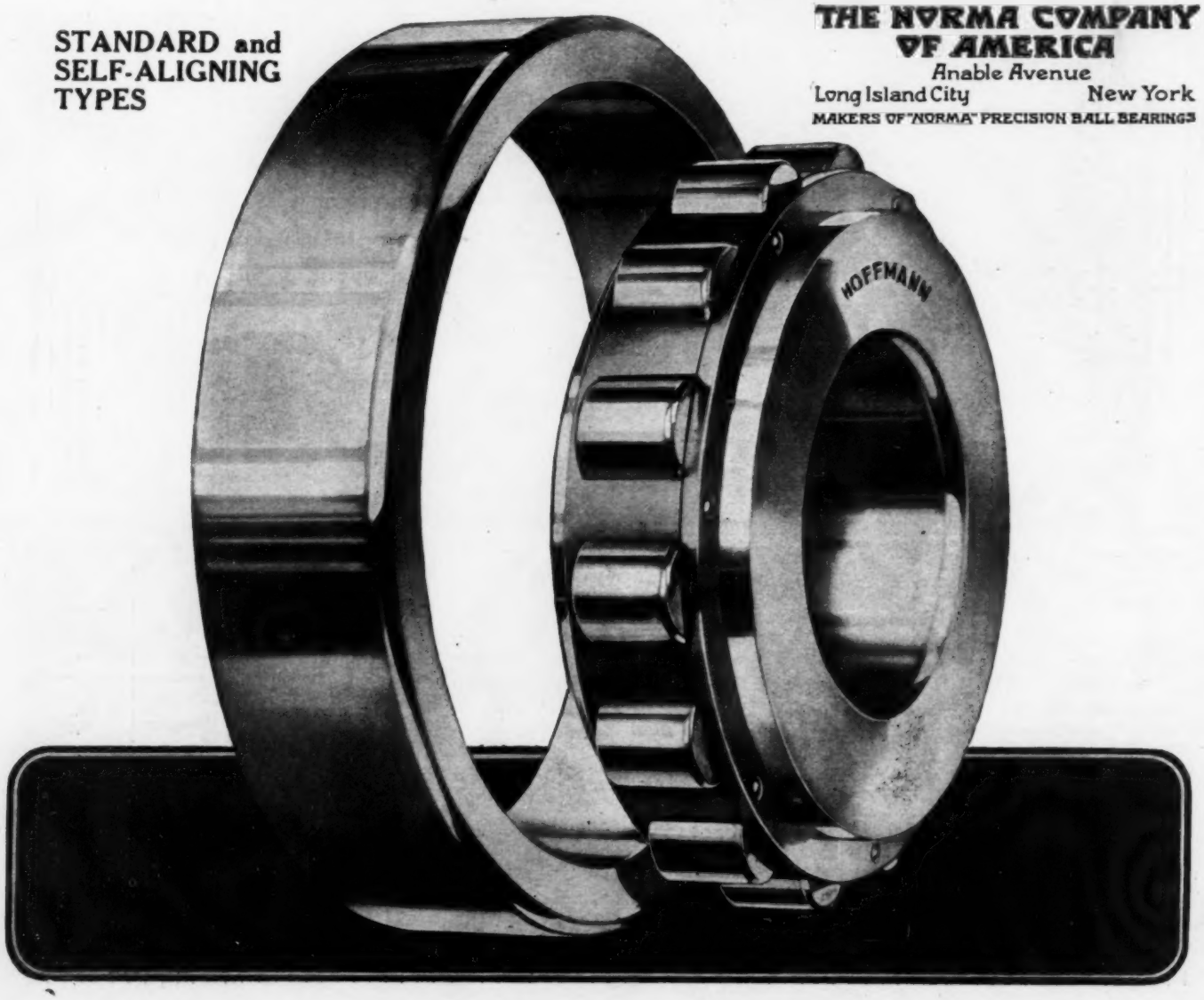
HOFFMANN PRECISION ROLLER BEARINGS

For Heavy Loads and Hard Service

Heavy-duty units manufactured to unequaled standards of precision; affording the maximum of serviceability under conditions involving heavy loads, temporary overloads, shock, jar and vibration; offering to manufacturers and users of electrical machinery for the steel plant new opportunities for power saving, reduced upkeep costs, and better service.

Our engineers will welcome an opportunity to work with yours, in applying these high-duty, high-precision bearings to your machines, with a view to securing maximum anti-friction efficiency, minimum maintenance costs, and continuity of service.

STANDARD and SELF-ALIGNING TYPES



THE NORMA COMPANY OF AMERICA
Anable Avenue
Long Island City New York
MAKERS OF "NORMA" PRECISION BALL BEARINGS

BENJAMIN

Makers of Things More Useful

An Installation of Benjamin Elliptical Angle Reflectors

Benjamin Elliptical Angle Reflector Socket

For use where overhead conditions make lighting from the side desirable.

For wide bays to supplement overhead lighting with intense lighting from the side.

They light up not only wide areas in a horizontal plane, but throw a flood of light on vertical surfaces as well.

Especially useful, indoors or out, where service conditions require a heavy duty unit.

The Crysteel Porcelain Enamel is easily cleaned and makes the reflector highly resistant to moisture, smoke, gases and the dust and dirt of heavy industrial processes.

Equipped with heavy type X weatherproof fitting and two-piece porcelain, easy-to-wire keyless socket. Benjamin lamp grip prevents loosening and falling of lamp under vibration.

Where there is the possibility of unauthorized removal or theft of lamps, they may be fitted with Self-Locking Socket.

Our nearest office will gladly give further information
Send for new Bulletin on Industrial Lighting

BENJAMIN ELECTRIC MFG. CO.
847 W. Jackson Blvd., Chicago
247 W. 17th Street, New York
580 Howard Street, San Francisco
Pittsburgh District: P. O. Box 807; Phone Court 2032

"For every requirement in Industrial Illumination"

Power Factor

Many industrial managers assume that once electric service has been installed they have reached the ultimate in economic operation. This is true in most cases, but, where power factor enters, the Duquesne Light Company can undoubtedly serve to lower your costs to a greater degree.

An analysis of your power factor will show either:

Poor Power Factor	*Good Power Factor*
1. Poor voltage regulation.	1. Good voltage regulation.
2. Excessive copper.	2. Big savings in copper.
3. Overheating of motors.	3. Long life of motors.
4. Increased cost of power due to line losses.	4. Minimum cost of power.
5. Loss in production due to low speed.	5. Constant speed of all equipment.

A power factor clause in your contract puts a premium on efficient operation. The services of our Power Engineer are available to you for consultation as to how your problem may be solved.

Live in and expand your business in Greater Pittsburgh

Duquesne Light Company

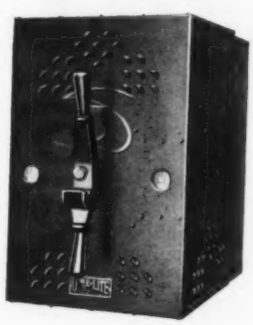
435 SIXTH AVENUE, PITTSBURGH, PA.

U-RE-LITE

U-RE-LITE Jr. (*250 volts D. C.*)
1 to 60 amps. inclusive.
Features: Overload or overload and Dalite (Direct acting Time limit)

U-RE-LITE Sr. (*250 volts D. C.*)
5 to 200 amps. inclusive
Features: Overload - Dalite (Direct acting Time limit.) No voltage or shunt trip. Bell ringer.

U-RE-LITE "W" (*250 volts D. C.*)
5 to 400 amps. inclusive.
Features: Overload - Dalite (Direct acting Time limit.) No voltage or shunt trip. Bell ringer.



U-RE-LITE "NX" (*250 volts D. C.*)
100 to 1250 amps. inclusive.
Features: Overload - Dalite (Direct acting Time limit.) No voltage or shunt trip. Bell ringer.

AUTO U-RE-LITE Sr.
5 to 150 amps. inc. at 220 volts A. C.
5 to 80 amps. inc. at 550 volts A. C.
Features: Overload - Dalite (Direct acting Time limit.) No voltage or shunt trip. Bell ringer.

AUTO U-RE-LITE Jr.
1 to 60 amps. inc. at 220 volts A. C.
1 to 15 amps. inc. at 550 volts A. C
Features: Overload - Dalite (Direct acting Time limit.) No voltage or shunt trip. Bell ringer

AUTO U-RE-LITE "W"
5 to 400 amps. inc. at 220 volts A. C.
5 to 300 amps. inc. at 550 volts A. C.
Features: Overload - Dalite (Direct acting Time limit.) No voltage or shunt trip. Bell ringer

CIRCUIT BREAKER ENGINEERS To AMERICAN INDUSTRY

The CUTTER COMPANY
ESTABLISHED 1888 (I-T-E) PHILADELPHIA

Fig. 1.

Fig. 2.

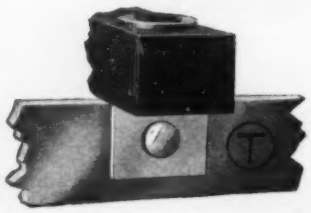


Fig. 3.

Fig. 4.

Iron and Steel Electrical Engineers:

You Iron and Steel Engineers represent probably the first body of men who individually and collectively appreciated that to obtain safety in switches something far more was necessary than just a safety box.

No body of men know better than you the unfortunate position in which safety switches have been placed because of a long drawn propaganda by salesmen and press eulogizing the safety box which keeps the operator away from the live parts of the switch. Such propaganda paid no attention whatever to the first necessity of safety in switches—namely the type of switch in the box that is to do the work.

From the beginning until now, there are few manufacturers and fewer contractors and engineers who pay enough attention to the construction of the knife switch proper, thinking as they do that safety switches mean a safety box surrounding most any kind of a switch.

Even the Underwriters in classifying safety switches speak of Class A, Class B, Class C or even Class AA in terms of boxes only—disregarding the switch entirely—an A box may contain the cheapest switch imaginable. One safe switch for industrial use is the Trumbull Type A manufactured for nearly twenty-five years. The Trumbull type A switch is machine made—built-up, most rigidly constructed and **quick-make** and **quick-break.** It will stand up under use and abuse.

The Illustrations Show

Figure 1—Foot-block and the pin that fastens the blades to the foot-block after it has been sweated.

Figure 2—Shows contact jaw complete.

Figure 3—Shows method of fastening the blade to the fibre cross-bar, making a unit of the blade and crossbar.

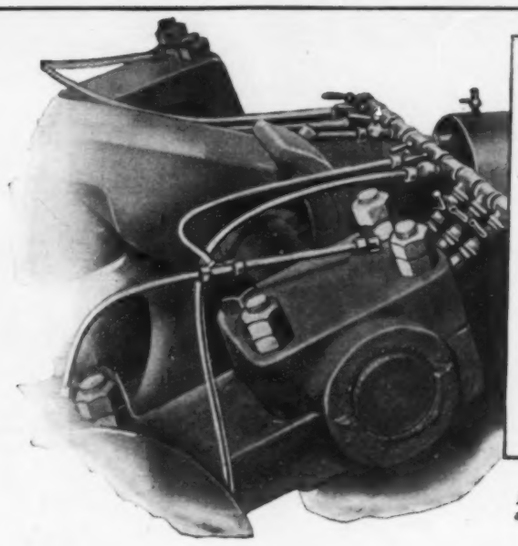
Figure 4—Shows long and strong quick make quick break spring that at no time is worked more than 50 per cent of its capacity.

The Trumbull Electric Mfg. Company

114 Liberty St., New York City
535 Mission St., San Francisco, Cal.

Plainville, Conn.

2001 W. Pershing Rd., Chicago, Ill.
Boston Philadelphia Atlanta



Note collar of grease at bearing's end

5 *things to fight* in plant operation

Poor Lubrication
Loss of Life or Limb
Fire Hazards
Interrupted Production
Machine Depreciation

THE Keystone Manifold Safety Lubricator combats them all in new, efficient ways.

Dirt—*friction's ally*

FRICTION hasn't a ghost of a chance with a pure lubricant correctly applied, but when dirt, grit, and dust take sides then there's a different story.

For with dirt inside a bearing, an abrasive action is set up, transforming the flying shaft into a miniature grinding wheel. Friction results. There is a power loss. Wear begins. And when wear starts costly trouble is inevitable.

Overcome this menace—you can. By forcing grease directly to the bearings under the high pressure obtainable with the Keystone Manifold Safety Lubricator a collar of grease is formed at the bearing's end. This practically seals the clearance between bearing and shaft. Dirt cannot enter.

The Keystone Manifold Lubricator presents a method of applying Keystone Grease under high pressure, to more than one bearing. Grease is fed positively — efficiently — without waste—thru pipe line leads directly to the bearing. Get the details. Write!

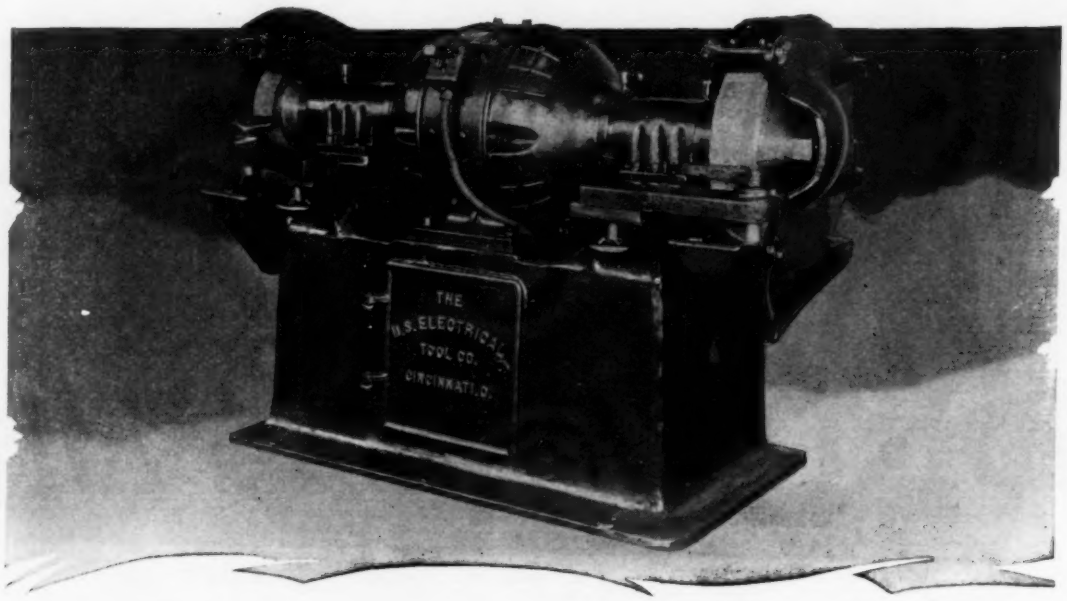
KEYSTONE GREASE

Keystone
Manifold Safety Lubricator

MULTIPLE FEED, HIGH PRESSURE GREASE LUBRICATING SYSTEM

THE KEYSTONE LUBRICATING CO. *Established 1884* **Philadelphia, at 21st and Clearfield Streets**

SKF



Ball Bearings on Electric Grinders
Eliminate Chatter—Maintain High Production

WHERE constant performance and accurate work are essential, it is imperative that double end grinders be accurately mounted, well-balanced and practically vibrationless. On the 10 H. P. electric grinder shown—operating at speeds of from 1200 to 1800 R.P.M.—Skayef self-aligning ball bearings on the spindle help maintain high production by the practical elimination of chatter and vibration due to wear of plain bearings.

Both thrust and radial loads are supported by Skayef self-aligning ball bearings and, as no appreciable wear occurs, even after years of running, the maintenance of precise original settings are insured, eliminating the necessity of frequent "take-ups" and adjustments.

Sealed housings prevent dust and grit from working into the bearings with consequent damage to balls and races. Lubricant is only required three or four times a year.

Our engineers are ready to aid you in solving any bearing problems in relation to your machine tool equipment.

THE SKAYEF BALL BEARING COMPANY
Supervised by SKF INDUSTRIES, INC., 165 Broadway, New York City

1135

LADD
WATER TUBE BOILERS

These Companies know the many practical and economical features of the Ladd design. LADD WATER TUBE BOILERS varying in size from 150 to 2650 H.P. are today satisfactorily serving these typical manufacturers:

U. S. Steel Corporation
Standard Oil Company
Wheeling Steel Corporation
Pennsylvania Railroad
Spang, Chalfant & Co., Inc.
Bibb Manufacturing Co.
Brownell Improvement Co.
Afton Development Co.
Empire Note, New York
E. C. Atkins & Company
American Window Glass Company
Union Switch & Signal Co.
McKeesport Tin Plate Company
U. S. Naval Training Station
Kentucky & W. Va. Power Co.
Baldwin Locomotive Works
Transcontinental Oil Co.
United Engineering & Fdry. Co.
Taggart Baking Company
Ford Motor Company

Mexican Coal & Coke Company
Union d'Electricite, Paris, France
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Argentine State Railways
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Mines Domenicles de la Sarre, France

THE GEORGE T. LADD COMPANY

First National Bank Building
PITTSBURGH, PA.

CHICAGO OFFICE: 528 McCormick Building
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WATER TUBE BOILER LADD

It Will Pay You To Read This

ROLLER-SMITH Type HA

Small Portable Alternating Current
Ammeters, Voltmeters and Wattmeters

are small enough for your pocket, traveling bag or tool kit; they are light and compact; they are accurate and durable and they are available in ranges up to 50 amperes, 300 volts and 8 K.W.

Each one is a **Roller-Smith instrument**—that is your guarantee.

Send for Bulletin AK-150.

ROLLER-SMITH COMPANY
Electrical Instruments, Meters and Circuit Breakers

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2131 Woolworth Bldg., NEW YORK

WORKS
Bethlehem, Penna.

BALTIMORE, 113 E. Franklin St.
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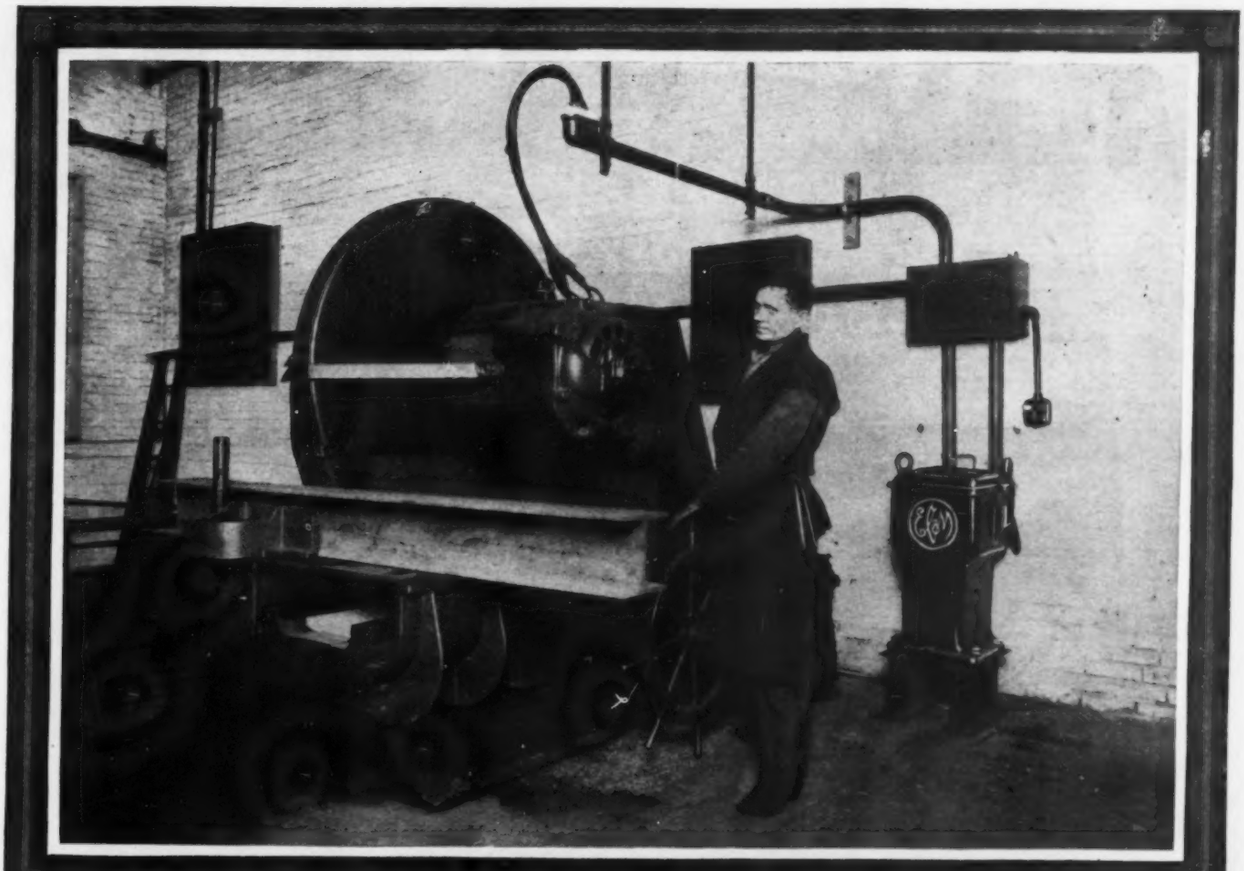
BOSTON, 141 Milk St.
BUFFALO, Ellicott Square
CHICAGO, 430 So. Green St.
CLEVELAND, 7016 Euclid Ave.
DALLAS, 2002 Live Oak St.
DENVER, U. S. Nat'l Bank Bldg.
DETROIT, American State Bank Bldg.
LOS ANGELES, Consolidated Realty Bldg.
MEMPHIS, 493 S. Main St.
MONTREAL, Power Bldg.
NEW ORLEANS, Whitney Central Bldg.
PHILADELPHIA, Otis Bldg.
PITTSBURGH, Keenan Bldg.
SALT LAKE CITY, Dooly Bldg.
ST. LOUIS, Railway Exchange Bldg.
ST. PAUL, Pioneer Bldg.
SAN FRANCISCO, 589 Howard St.
SCRANTON, 939 Capouse Ave.
SEATTLE, Hinckley Bldg.
TORONTO, 183 George St.



PERHAPS

THIS MAN IS INTELLIGENT ENOUGH TO START THIS RYERSON SAW WITH A HAND COMPENSATOR

BUT

THE OWNER OF THE SAW IS TAKING NO CHANCES. HE HAS INSTALLED AN E. C. & M. AUTOMATIC COMPENSATOR

Write for Bulletin 1042-D

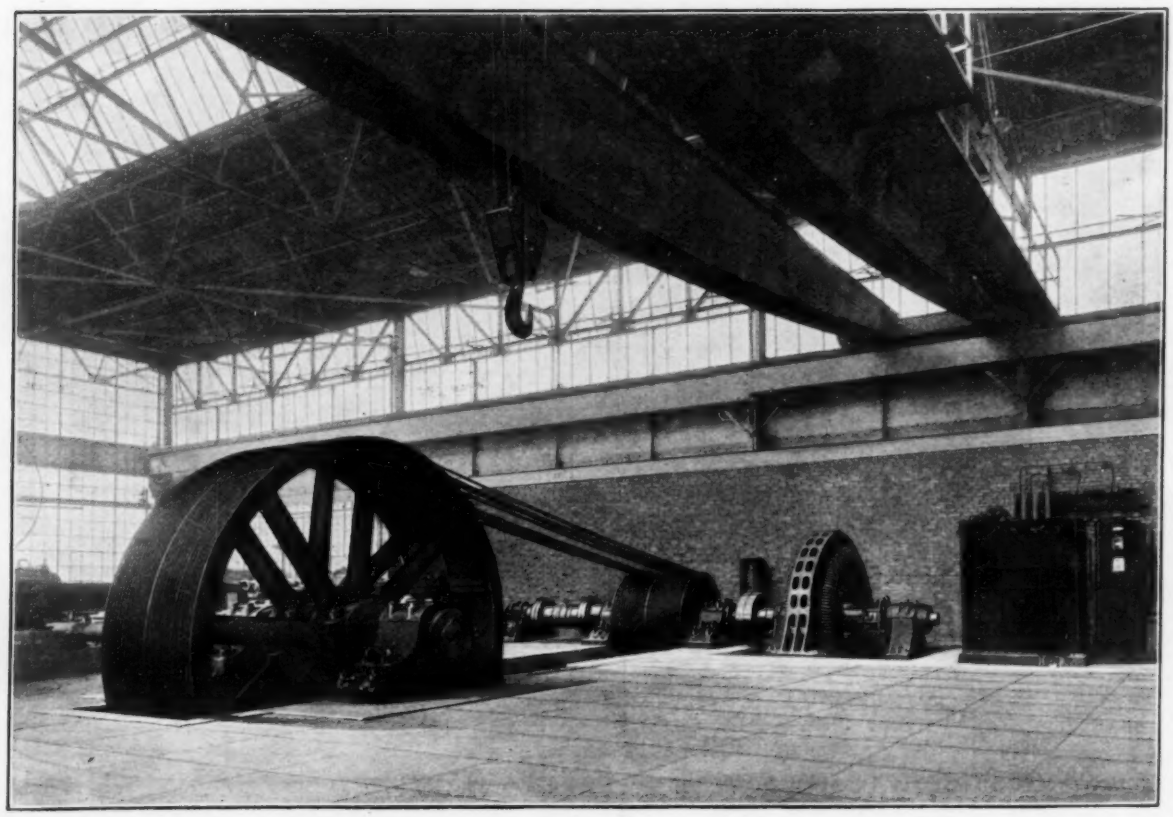
THE ELECTRIC CONTROLLER & MFG. CO.

CLEVELAND, OHIO

BIRMINGHAM - BROWN-MARX BLDG.
CHICAGO - CONWAY BLDG.
CINCINNATI - 1ST NATIONAL BANK BLDG.
DENVER - 3535 WALNUT ST.
DETROIT - DIME BANK BLDG.
LOS ANGELES - O.E. THOMAS CO.
BOSTON - 49 FEDERAL ST.
NEW YORK - 50 CHURCH ST.
PHILADELPHIA - WITHERSPOON BLDG.
PITTSBURGH - OLIVER BLDG.
SAN FRANCISCO - CALL BUILDING
SEATTLE - 524 1ST AVE. SOUTH
TORONTO - TRADERS BANK BLDG.

ALLIS-CHALMERS

Tube Mill Drive



1200 H.P., 4600 Volt, 60 Cycle, 3 Phase, 257 R.P.M.
Wound Rotor Induction Motor
with
Automatic Liquid Slip Regulator

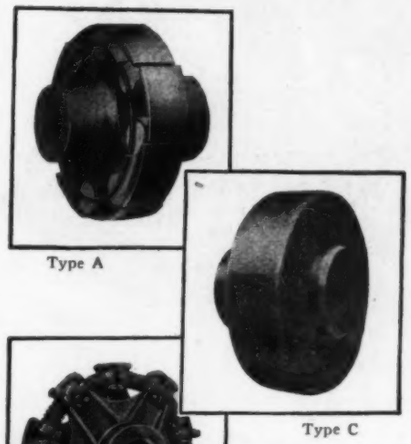
ALLIS-CHALMERS PRODUCTS
Electrical Machinery
Steam Turbines
Steam Engines
Gas and Oil Engines
Hydraulic Turbines
Crushing and Cement Machinery
Mining Machinery

ALLIS-CHALMERS MANUFACTURING COMPANY

MILWAUKEE, WISCONSIN. U.S.A.

ALLIS-CHALMERS PRODUCTS
Flour and Saw Mill Machinery
Power Transmission Machinery
Pumping Engines-Centrifugal Pumps
Steam and Electric Hoists
Air Compressors - Air Brakes
Agricultural Machinery
Condensers

USEFUL INFORMATION
For the Iron and Steel Engineer
Some Nuttall Products He Needs Every Day



Type A

Type C

Type B

Flexible Couplings

Type A—Rubber Buffer Type. Good for 10 to 1300 H.P., 400 to 2700 r.p.m., 1¼" to 13" shafts, outside diameters range from 5½" to 48".

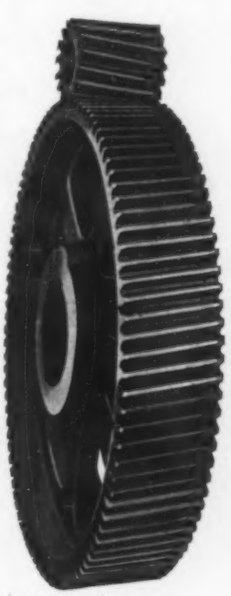
Type B—Cast Steel, Spring Type. Good for 100 to 4875 H.P., 200 to 1150 r.p.m., 3" to 18½" shafts, 13" to 78" outside diameters.

Type C—Enclosed, Spring Buffer Type. Good for 85 to 2700 H.P., 440 to 3600 r.p.m., 1½" to 15½" shafts, outside diameters 6½" to 52".

Our Gear Limits

Type of Gear	Max. Diam.	Max. Pitch
Planed Bevel	192"	6½"
Generated Bevel	25"	1½"
Cut Spurs	360"	6"
Planed Spurs	240"	6"
Generated Spurs	138"	1 DP
Worm Wheels	138"	1 DP
Spiral Gears	138"	1 DP
Helical Gears	138"	1 DP
Herringbone Gears	140"	6"

A complete descriptive book, full of valuable data, will be sent free on request.



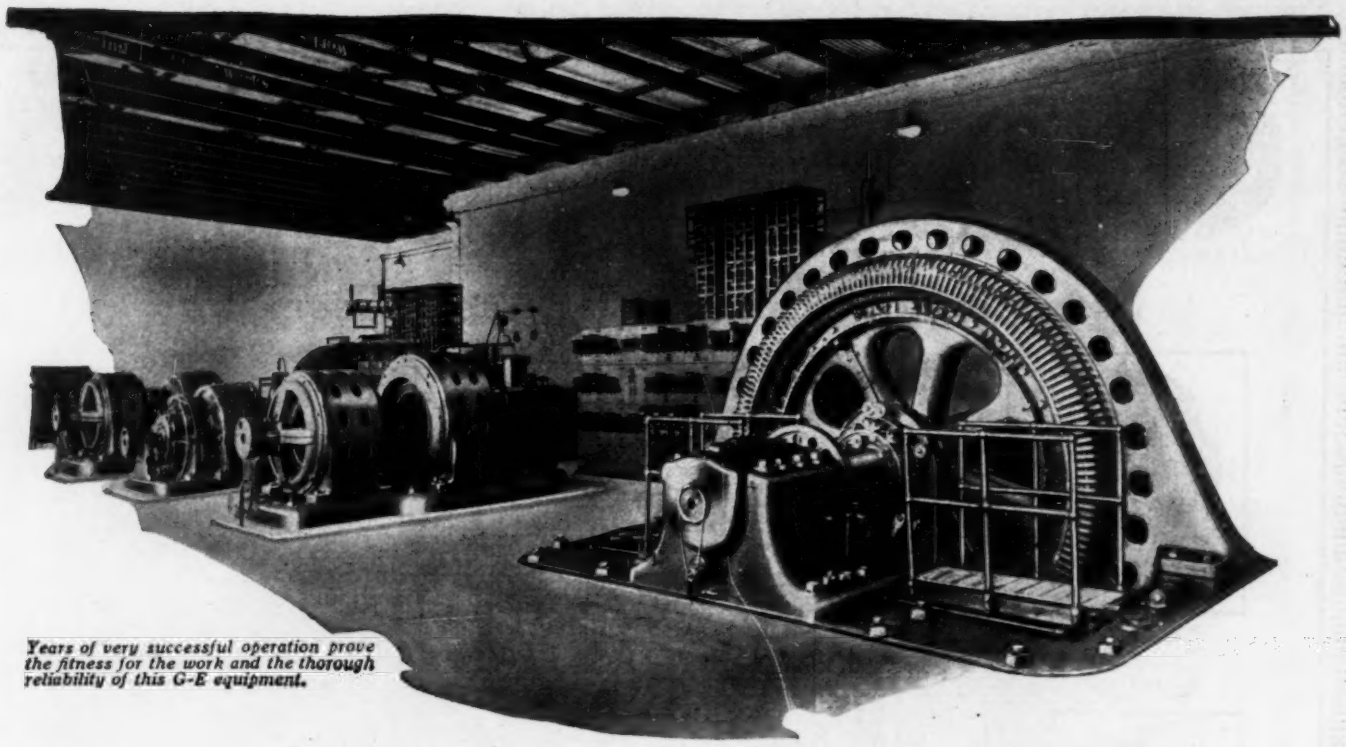
A Nuttall Helical Gear Set

R.D. NUTTALL COMPANY
PITTSBURGH PENNSYLVANIA

Philadelphia Office
420 Land Title Bldg.

Chicago Office
2133 Conway Bldg.

Nuttall



Years of very successful operation prove the fitness for the work and the thorough reliability of this G-E equipment.

Where the Scherbius System qualifies

In general by far the greater part of the product of adjustable speed mills is rolled within a small range of speed approximating midway between maximum and minimum speeds.

The double range Scherbius system is especially adapted to meeting these conditions, for it permits operating at maximum efficiency throughout this range of maximum production as well as giving in general higher efficiencies at all speeds than can be obtained with any other system.

That the Scherbius system of control meets all the exacting requirements of adjustable speed mills is evidenced by the fact that steel mills have purchased 65 of these equipments.

The choice of control system to meet *any* condition can only be made after a careful study of the problem, and the steel mill specialists of the General Electric Company are always ready to help solve your problems.

General Electric Company
Schenectady, N. Y.
Sales Offices in all Large Cities

GENERAL ELECTRIC

43B-80

Steel Muscle Is Cheaper Than Man Muscle

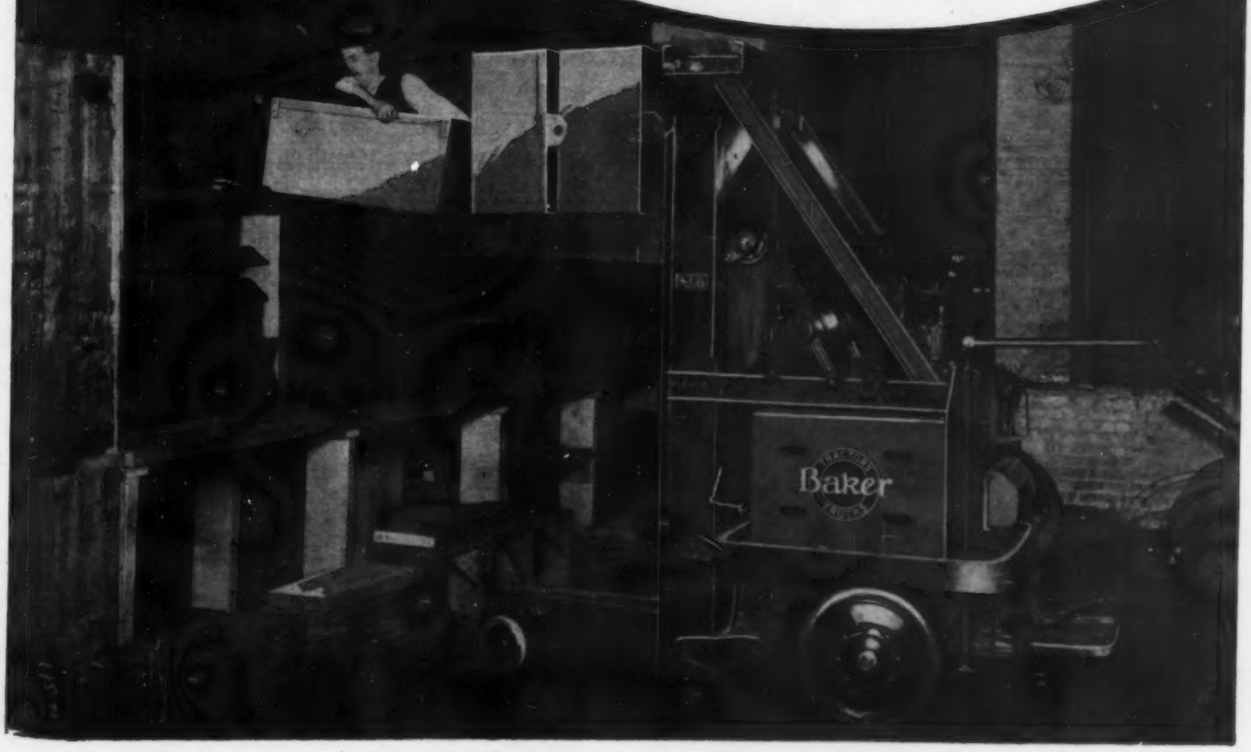
HIGH production costs cannot be blamed on inefficient labor alone. The inefficient manufacturer who uses more human energy than necessary is just as much at fault. Steel muscle is cheaper than man muscle. Notice, for instance, how the Hy-lift truck illustrated below saves the labor of many hand truckers.

Picking its load up at the floor level, this sturdy truck weaves its way down narrow aisles, up steep ramps and around sharp corners to lift and deposit the material just where it is wanted.

The various types of Baker Iudustrial tractors and trucks do the work of from 5 to 20 men. Write for our completely illustrated catalog, or ask to have a Baker engineer study your problems and then recommend the equipment that will do most to reduce the material-handling item on your production costs.

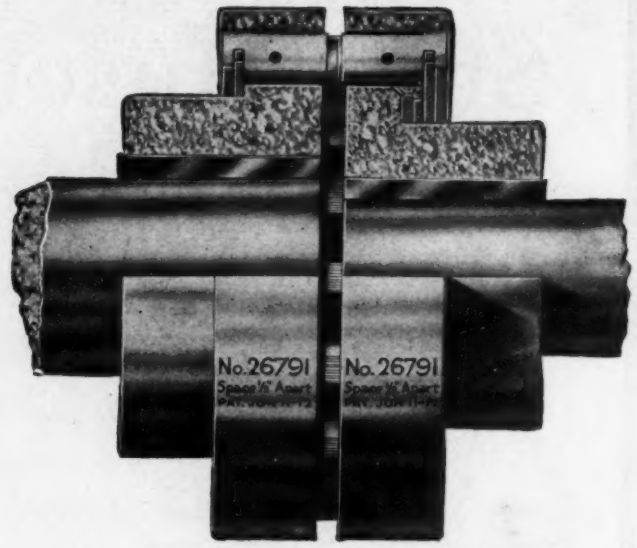
Baker Industrial Division
THE BAKER R & L COMPANY · CLEVELAND, OHIO

ELECTRIC TRACTORS AND TRUCKS
TRADE-MARK REG. U.S. PAT. OFF.
Baker



FRANCKE
FLEXIBLE COUPLINGS

"They make good machines last longer"



All Metal-Durable
¼ H.P. to 5,000 H.P.
Any Speed.

The **Heavy Pattern Type** Francke flexible coupling is recommended for drives from 1 H.P. to 500 H.P. and to handle "accidental" misalignments, such as are usual and to be expected even when reasonable care is used to see that good alignment is obtained when the machines are installed.

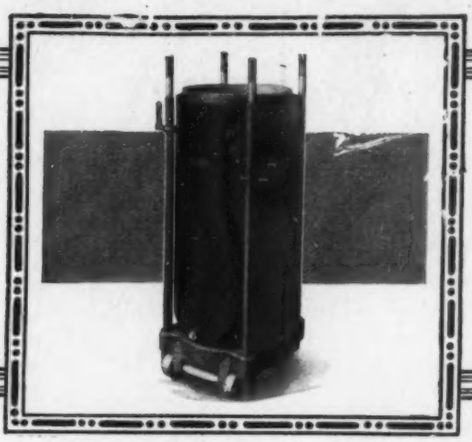
Uneven bearing wear, movements of the machine frames due to operating stresses or due to heat expansion, movements due to vibration, and uneven settling of foundations, all of these are to be expected when operating direct-connected machinery.

The Heavy Pattern Francke will take care of misalignments and give many years of service under average operating conditions.

Even when an operating accident or lack of reasonable operating care causes excessive misalignment, the Francke will prevent destructive strains from damaging the connected machines. For under such conditions the easily replaced pin units act as a safety device.

Up-to-date data and description of the various types of Francke flexible couplings are given in Bulletin No. 37.

SMITH & SERRELL
Coupling Specialists Since 1912.
47 Central Avenue, Newark, N. J.
District Office, Fulton Building, Pittsburgh



A secondary tank designed to afford protection against oil and flame throwing even in case of puncture to inner tank. Sometimes called "double" or "spill" tank.

Double Tank

AS a protection against fire-hazard in high-voltage, high-powered systems, there is nothing quite the equal of "double" tank construction.

They are designed to prevent cell fires—even in case of puncture to inner tank.

They reduce dangerous flame throwing.

They condense and isolate the gases.

They require no additional cell construction and for most installations no additional space.

CONDIT "double" tanks—and they're exclusively a CONDIT feature of design and construction for single unit, common frame or truck type oil circuit breakers—reduce fire-hazard to a minimum and provide low cost insurance. Specify them.

"Get in touch with CONDIT."

CONDIT ELECTRICAL MFG. CO.
Manufacturers of Electrical Protective Devices
South Boston, Mass.
Northern Electric Company
Sole Distributor for the Dominion of Canada

CONDIT
Features

1. "Double" tanks.
2. Energy Absorption.
3. Self-contained mufflers.
4. Massive rigid frames.
5. Laminated contacts.
6. Truck type units.

CONDIT

The Cost of One Motor Failure

The expense in repairs alone for your last motor failure probably many times exceeded the cost of changing over the motor to Hyatt roller bearings.

If proper charges for lost production are included, the cost of motor breakdowns becomes even more excessive.

Whether caused by grounded *oil-soaked windings,* or *actual bearing wear,* the use of durable, reliable Hyatt bearings mounted in oil-tight housings will prevent further trouble, by keeping windings free from grease and dirt and by holding the armatures permanently in position.

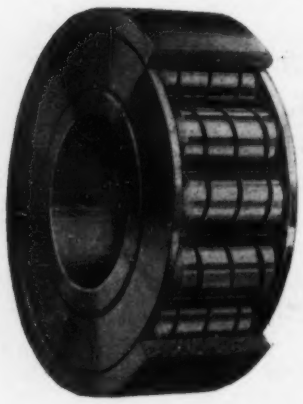


Figure out the full cost of your last motor failure—then write us for details as to how a recurrence may be prevented.

HYATT ROLLER BEARING COMPANY
NEWARK, NEW JERSEY

HYATT ROLLER BEARINGS FOR ELECTRIC MOTORS

"They Have the Same Quality as P & H Traveling Cranes"

"That's how we first got interested in the P&H Corduroy Crane."

"As users of a number of P&H Overhead Traveling Cranes, we received a circular telling about their Corduroy Cranes for industrial use, and we were glad to let them tell us more about them."

"That one machine you see out there," went on Mr. Warren of the Hart Mfg. Co., "has paid for itself in 11 months. It gets around so easily, needs no road or tracks—and is ready to go before you can say Jack Robinson."

If *you* have not seen any of these Cranes operating in plants of the

American Radiator Co.
Standard Oil Co.
Aluminum Co. of America
American Brass Co.
American Manganese Steel Co.
American Steel & Wire Co.
The Bettendorf Co.
The Ingalls Iron Works Co.
Malden & Melrose Gas Light Co.
Mohawk Valley Cotton Mills
North & Judd Mfg. Co.
San Pedro Lumber Co.
Standard Sanitary Mfg. Co.
Sullivan Machinery Co.
Western Pipe & Steel Co.

we suggest dropping us a line so that a copy of our Bulletin 40-X can be mailed to you.

Pawling & Harnischfeger Co.

Established in 1884

3855 National Avenue, Milwaukee, Wis.

New York	Chicago	Pittsburgh	Philadelphia
Phoenix	Salt Lake City	Denver	Los Angeles
San Francisco	Portland	Seattle	St. Louis
Birmingham	Memphis	Dallas	Atlanta

Kansas City

P&H CORDUROY CRANES

1891 — 1924

MORGAN
Construction Company

Worcester, Mass., U.S.A.

Designers and Builders of

Morgan Continuous Mills

for

Billets, Sheet Bars, Skelp, Merchant-Bars, Hot-Strip, Rods

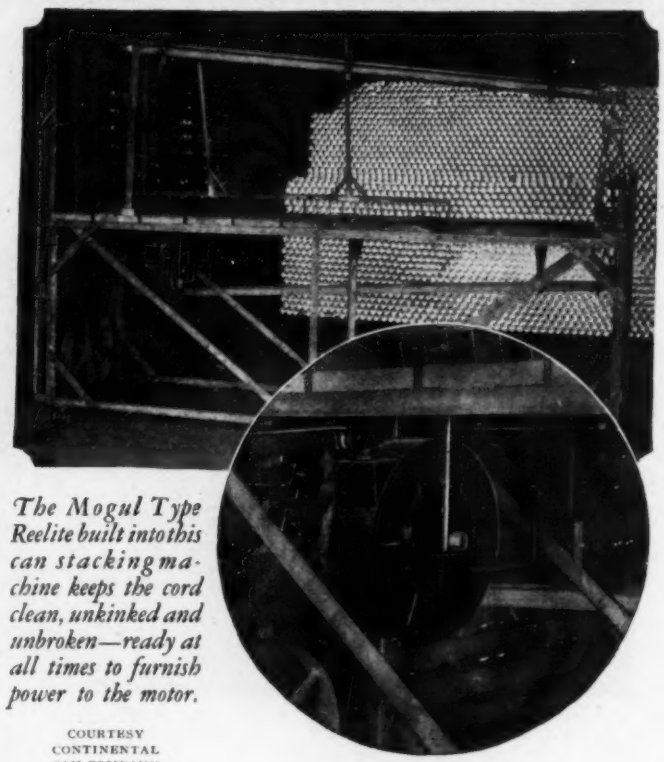
also

Wire Drawing Machines
Producer Gas Machines
Straightening Machines
Isley Reversing Valves
Re-Heating Furnaces
Reducing Gear Units
Shears

Our Engineering Department

is prepared to solve successfully your problems in design or arrangement of plant and equipment from open hearth to finished product

1891 — 1924



The Mogul Type Reelite built into this can stacking machine keeps the cord clean, unkinked and unbroken—ready at all times to furnish power to the motor.

COURTESY CONTINENTAL CAN COMPANY

True Portability for the Portable Machine

The new Mogul Type Reelite opens new fields for development in portable machinery. This unit can be incorporated in new machines or attached to existing devices to definitely end the worries of portable cord maintenance. There are many situations where bare current conducting rails are not practical from either a safety or operating standpoint. And loose cables dragged over floors, through oil, and under the wheels of trucks always require repair with a loss of operating time for the machine.

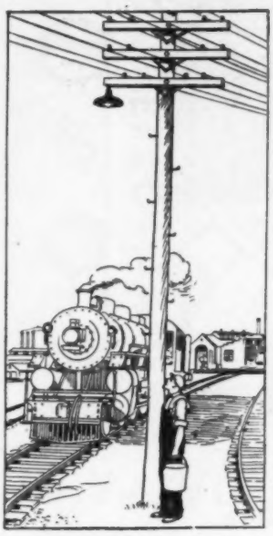
The Mogul Type Reelite pays out cord of practically any size and number of conductors and then automatically retrieves it when no longer required. It is furnished with 1″ male-threaded hubs for mounting on the machine, and knockout for conduit connection for current supply.

Our engineers will be glad to give any information or assistance possible in the adaptation of Reelite to your requirements.

APPLETON ELECTRIC COMPANY
Factory and General Offices
1717 Wellington Avenue
CHICAGO

MOGUL TYPE
Reelite
REG. U.S. PAT. OFF.

Not only **Safety** but **More Light** and **Longer Life** of the Reflector



Difficult and Dangerous

Even if he did climb up, he could not hold the reflector so as to do a good job of cleaning.

DIRTY REFLECTORS DO NOT REFLECT

The greatest problem in reflector-cleaning is how to get at it.

THOMPSON

Safety DISCONNECTING Hangers

—enable high lamps to be lowered away from the electric circuit for cleaning and renewals.

The Hanger is as necessary to the reflector as the reflector is necessary to the bulb.

The reflector 'costs' more than the bulb and does not 'produce' any light; that is done only by the bulb—and only a 'clean' reflector 'saves' light.

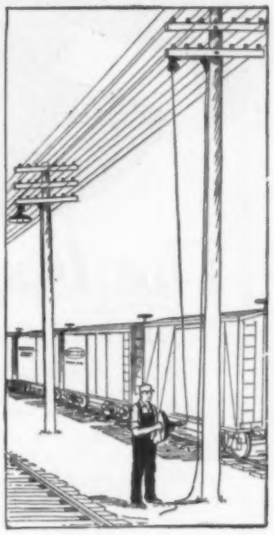
Consider what the reflector-cleaner has to do to get at the high lamps.

Why lose the benefit of your reflector investment for want of adequate facilities for keeping them clean?

Get Catalog B-21 for details.

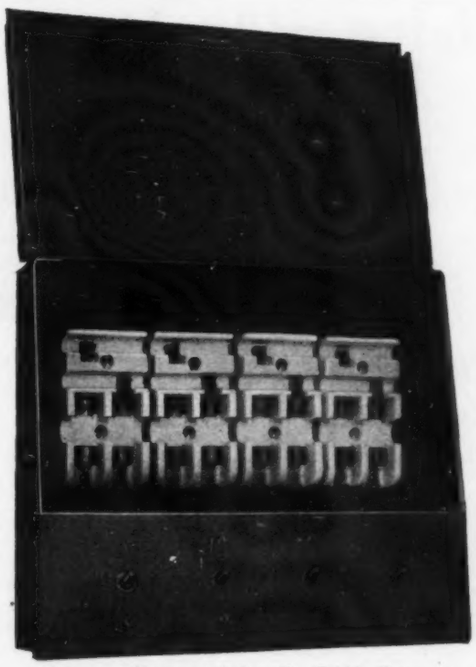
The Thompson Electric Company

226 St. Clair Ave., N. E.
CLEVELAND, OHIO, U. S. A.



Easy and Safe

Why not add enough to the equipment to make it workable.



Wayman Safety Switch-Box No. T-900, Open

THE WAYMAN "FOUR IN ONE" UNIT

The New Standardized Method of Grouping and Controlling Several Units

Where four or more lighting units exist the WAYMAN SAFETY SWITCH BOX concentrates the number of boxes into one single unit, thereby saving space and valuable time in installations.

It combines FOUR circuits in ONE; conveniently equipped box with 3 to 30 ampere, 250 volt New Code Cutouts or 3 to 30 ampere, 125 volt plug cutouts with various switches; the whole properly guarded and protected against meddlesome interferrence.

This "FOUR IN ONE" Safety Switch Box because of its simplicity, the limited space required and the small item of expense attached to its installation is especially adapted for use in Industrial Plants.

If you are interested in a Switch Box of this type, return the coupon, no obligation incurred whatever.

THE WAYMAN ELECTRIC & MFG. COMPANY

East Palestine, Ohio

The Wayman Elec. & Mfg. Co.,
East Palestine, O.

Gentlemen:

Please send me further information about your FOUR IN ONE—
I want to learn more about your Safety Switch Box and how
it can effect economy in our plant.

Name.....

Address.....

City..... State.....

Business.....

Title or Position.....

The Inside Facts
on Renewable Fuses

Although all fuses look alike on the out-side there is a great difference in the inside design and construction which determines the efficiency of the fuse itself.

Each Trico renewable element is composed of a fusible link surrounded by a finely divided, arc-choking powder, encased in a kraft container which is virtually a fuse within itself.

This powder-packed element makes the Trico Renewable Fuse more efficient than any other kind because the fuse link is supported and kept in shape when heated during momentary overloads, preventing premature "blowing" and consequent expensive shutdowns.

You cannot char the fibre casing as the powder packing chokes the flash of the melting fuse link preventing pitting of metal terminals or blades, eliminating blackening and heating of contacts so that the Trico Fuse is the easiest to renew.

Trico Renewable Fuses are made in all standard sizes in 250 and 600 volts, and are fully approved by Underwriters Laboratories.

Write for address of our nearest Sales Office.

TRICO FUSE MFG. CO.
MILWAUKEE, WIS.

TRICO FUSES
REG. U. S. PAT. OFF.
Renewable Cartridge

FREE FOR YOU

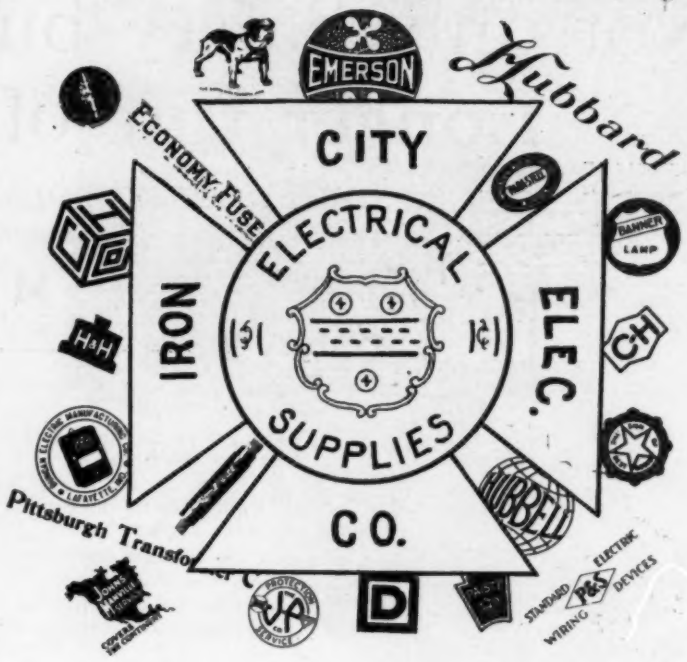
Tear off this coupon and mail it to us for free sample Trico Powder-Packed Fuse Plug—"Famous for its Performance." No obligation—simply sign and mail.

Name .....

Position .....

Company .....

Address .....



The Trade Mark

of the

Iron City Electric Co.

436-38 Seventh Avenue

Pittsburgh, Pa.

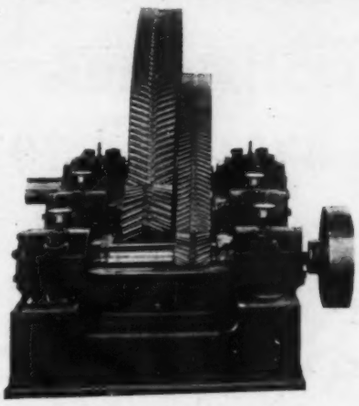
REPRESENTING

"The House That Service Built"

IS BACKED BY A GROUP OF

TRADE MARKS

of Well Known Manufacturers Guaranteeing the Quality of the Goods You Receive



Double Reduction HBR. Drive. 10 to 200 H.P.
Ratios 10 to 100.

Small Single Reduction HBR. Drive. 20 to 100 H.P.
Ratios 2 to 10.

FAWCUS HERRINGBONE GEAR SPEED REDUCERS

Fawcus Herringbone Gear Reductions are equipped with Hyatt "Roller Bearings" for motor and small engine reductions to slow speed compressors, pumps, fans, line shafts, conveyors, elevators, or any type of slow speed machinery. These reduction gears are sold at a low price, combining all the good points of the FAWCUS HERRINGBONE GEAR DRIVE (98% efficiency, elimination of wear, and vibration), yet at a price that will compare favorably with any other speed reducer, efficiency and durability being considered.

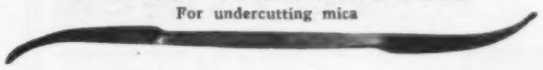
FAWCUS MACHINE COMPANY, Pittsburgh, Pa.

REPRESENTATIVES:

New York, N. Y., R. C. Brown, 84 Pine St.
Chicago, Ill., Hodgart & Co.
Milwaukee, Wis., L. E. Miedinger.
Birmingham, Ala., G. R. Mueller Co.
San Francisco, Cal., K. W. Eichelberger.
Portland, Ore., Coast Steel Machinery Co.

Use "Imperial" Commutator Stones

COMMUTATOR SLOTTING FILES
For undercutting mica



GOODNITE CLEANING TOOL
For cleaning Commutator slots

2. They Cut Copper Faster Than a Turning Tool.

(Advantage No. 3 will be given next month.)

2340 Users on March 1st—A Gain of 119 for February

Send the Coupon for Information

We can supply you with

Commutator Grinders
Slotting Machines
Commutator Cement
Insulating Beads
Insulating Varnish
Gauze Wire Brushes
Portable Blowers

THE MARTINDALE ELECTRIC CO.,
11729 Detroit Ave., Cleveland, Ohio.

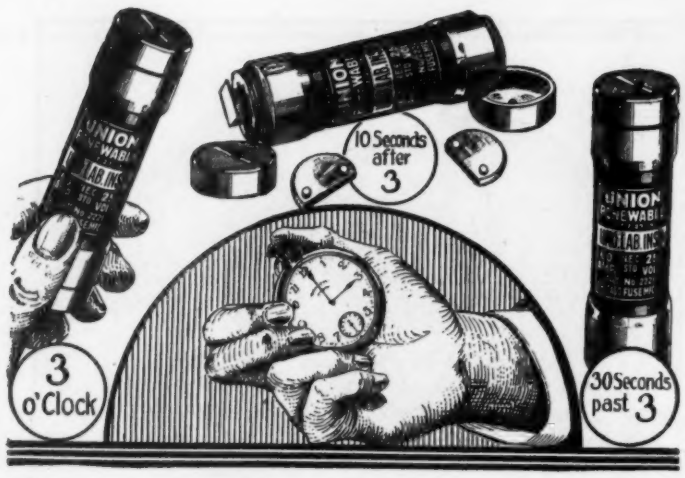
Gentlemen: Please send me information about your products.

Name and Title .....
(Please print)

Company .....

Street .....

City and State .....



New Fuses from Old in 30 Seconds

You can replace a blown link in "Union" ferrule-type fuses in 30 seconds.

Quick renewal is possible with "Union" Renewable Fuses because of few parts, simple construction, and—most important of all—design which prevents fusing and sticking of metal parts.

The vanishing link and specially treated washers in "Union" knife-blade renewable fuses make it impossible for metal parts to stick in

'UNION' RENEWABLE FUSES

Consequently, there is no excuse for workmen to scrap "Union" Fuses instead of putting in a new link. That is one feature which saves money.

And here is another reason why:

"The 'Union' saves more than ANY other renewable fuse."

Heavy, rugged design enables the "Union" to withstand a greater number of blowouts than other makes. So, fewer "Union" Fuses are needed.

Both "Union" Renewable and Non-Renewable Fuses are approved by the National Board of Fire Underwriters.

You can get them from your electrical jobber or dealer.

Ask for interesting catalog.

Chicago Fuse Mfg. Co.

Manufacturers also of Switch and Outlet Boxes, Cut-out Bases, Fuse Plugs, Fuse Wire and Automobile Fuses.

CHICAGO NEW YORK

UNION

Reg. U. S. Pat. Off.

Chutree

Why do American women wear furs in summer?

For the same reason that the India woman carries a chutree umbrella on a sunshiny day.

The man who can explain the reason is the man who can say "I understand women."

But he doesn't understand women any more than the average operator understands carbon brushes.

He *thinks* he does—but he *doesn't*. There are just as many angles to brush performance as there are to women's doings.

That is why we are impressing on makers and users of motors the urgency of letting Morgan brush engineers *prescribe* Morganite brushes.

They come the nearest to knowing *all* the angles of the brush business—because of their highly specialized experience.

MORGANITE BRUSH CO., INC.
519 West 38th St., New York City
DISTRICT ENGINEERS AND AGENTS

MORGANITE

Electric Power Equipment Corp., 412-420 North 18th St., Philadelphia, Pa.

O. T. Hall, Sales Engineer, 1926 Edmonson Ave., Baltimore, Md.

Electrical Engineering & Mfg. Co., 909 Penn Ave., Pittsburgh, Pa.

Electrical Engineerng & Mfg. Co., 422 Union Bldg., Cleveland, Ohio.

Special Service Sales Co., 502 Delta Bldg., Los Angeles, Calif.

Special Service Sales Co., 202 Russ Bldg., San Francisco, Calif.

Electrical Engineering & Mfg. Co., 607 Mercantile Library Bldg., Cincinnati, Ohio.

Railway & Power Engineering Corp., Ltd., 131 Eastern Ave., Toronto, Ontario, Canada.

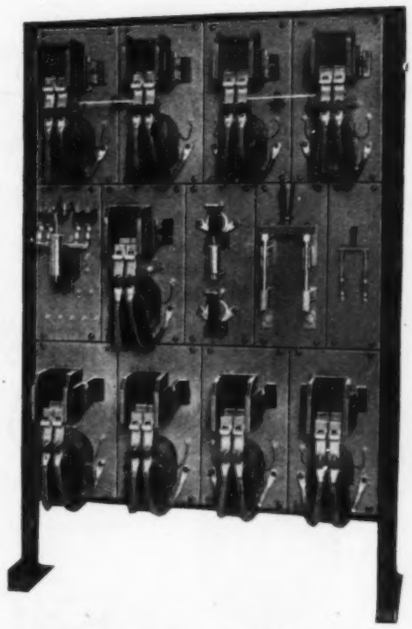
J. F. Drummey, 75 Pleasant St., Revere, Mass.

Automatic Motor Starters and Controllers

FOR

Alternating and Direct Current Electric Motors

May we send our nearest representative to see you?



150 H.P. Type 4750 Full Speed Reversing Mill Controller

ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

Electrical Engineering and Manufacturing Company

General Offices:

PITTSBURGH, PA.

We are prepared to furnish your requirements in the following materials and equipment:

"MORGANITE" Carbon-Graphite Metal Brushes.

"ROWAN" Automatic Controllers and Starters.

"SUMET" Bronze and Babbitt Bearing Metals.

"DUTCHESS", Empire or Varnished Cloth and Tape.

ELECTRICAL INSULATING Varnishes and Compounds.

"BELL" Cedar Poles.

CROSSARMS; Douglas Fir and Pine.

LINE MATERIALS; Hangers, Brackets, etc.

TRACK GRINDERS; Reciprocating and Rotating.

"AJAX" Welding and Bonding Machines.

MINE HOISTS and Winches, Car Pullers, etc.

HIGH and **LOW** Tension Insulators.

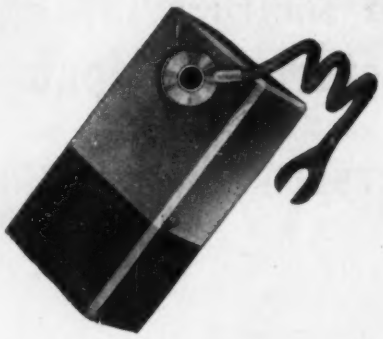
"ELPECO" High and Low Tension Switching Equipment, Bus Fittings, etc.

We have a corps of expert engineers, specialists in the above lines, who will be glad to give immediate attention to your inquiries or to see you at your request for consultation regarding applications or equipment. Call or write our nearest office.

CINCINNATI, OHIO
607 Mercantile Lib. Bldg.
Phone Maine 3257

CLEVELAND, OHIO
320 Union Bldg.
Phone Prospect 1252

PITTSBURGH, PA.
907-909 Penn Ave.
Phone Grant 6693-4
P. & A. Main 244



We Know What You Want

U. S. G. Brush engineers have made a study of the requirements of steel mills and are in a position to recommend and furnish carbon, graphite or metal brushes for that service which are absolutely guaranteed to be satisfactory.

If your machines are not yet equipped with U. S. G. brushes it will be to your advantage to write for Catalog B-3—really a text book on brushes.

USG

on every brush

The United States Graphite Company

Main Office and Factory

Saginaw, Michigan, U. S. A.

BRANCHES: New York Pittsburgh St. Louis Denver Philadelphia Chicago San Francisco

ELECTRIC RUMSEY EQUIPMENT

ESTABLISHED 1895

RUMSEY ELECTRIC COMPANY

ELECTRIC SUPPLIES and MACHINERY

1007 Arch St., PHILADELPHIA

FACTORY DIRECT REPRESENTATIVES

EFFICIENT

RELIABLE

SERVICE

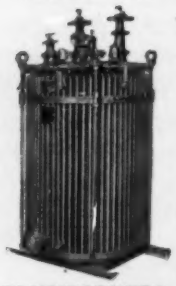
HIGH TENSION

ELPEco — Electric Power Equipment Co. — Philadelphia, Pa.

EQUIPMENT

LAPP
HIGH VOLTAGE
INSULATORS

PITTSBURGH



TRANSFORMERS

STORE AND OFFICE BUILDING
WAREHOUSE, 1010 CHERRY ST.

SANGAMO

METERS

BUILT LIKE A WATCH

"Sirocco"

AMERICAN BLOWER CO.
VENTILATING FANS
AND BLOWERS

C-H

CUTLER-HAMMER
CONTROLLING
DEVICES

UNITED STATES
ELECTRIC TOOLS

ALLIANCE CRANES

Largest Builders of the World's Largest Cranes

204 of 100 Tons Capacity and Over

STANDARD CRANES

55	100	tons
2	115	tons
42	125	tons
24	150	tons
22	175	tons
2	200	tons
1	225	tons
1	250	tons
3	430	tons

STRIPPING CRANES

8	100	tons
1	125	tons
19	150	tons
13	200	tons
1	Single Ram, 320	tons

COMBINATION CHARGERS AND STRIPPERS

3	100	tons
3	150	tons
4	200	tons

Pittsburgh Transformer Company

Largest Manufacturers of Transformers Exclusively in the United States

Pittsburgh, Pennsylvania

LAPP HIGH VOLTAGE PORCELAIN

Did you ever hear of a failure of a Lapp Insulator?

Seven years of production—including highest voltage pin and suspension types —without a failure!

There is the reason for use of Lapp Insulators, besides which—for "trimmings" —they provide unexcelled mechanical strength.

Lapp vacuum process of porcelain production, surfaces of porcelain glazed all over, Lapp over potential test methods.

LAPP INSULATOR CO., Inc., LeRoy, N. Y.

S. H. LANYON
509 New Call Bldg., San Francisco

O. H. Davidson Equipment Co.
1633 Tremont St., Denver

Commercial Electrical Supply Co.
Broadway and Spruce St., St. Louis

J. E. Sumpter Co.
940 Security Bldg., Minneapolis

F. R. Jennings Co.
805 Ford Bldg., Detroit

Robertson-Cataract Electric Co.
Buffalo

J. W. Fraser & Co.
Charlotte, N. C.

Rumsey Electric Co.
1007 Arch St., Philadelphia

Shield Electric Co.
149 Broadway, New York City

W. D. Hamer Co.
518 Trac. Term. Bldg., Indianapolis

Union Electric Co.
933 Liberty Ave., Pittsburgh

Wetmore-Savage Co.
76 Pearl St., Boston

Jas. J. Niven & Co.
Wellington, New Zealand

SAND—is the only cure for *slippery crane runways*

"IT TAKES SAND TO WIN"

Do you allow your men to pour it on with a bucket?——

Or do you allow your cranes to be operated on slippery runways?

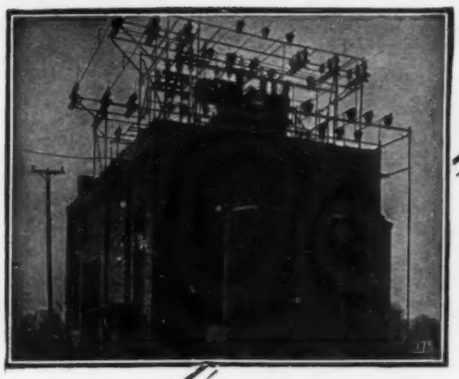
Both methods endanger your cranes, the lives of your operators and the men on the floor.—This also means unnecessary delays and losses.

Apply sand at the right time, the right place and in the proper amount by equipping your cranes with Lintern Electro Magnetic Sanders.

A number of plants are now in the process of equipping all of their cranes with Sanders. They will secure efficient and economical operation with all hazards due to slippery rails eliminated.

THE NICHOLS-LINTERN COMPANY

7960 Lorain Avenue **Cleveland, Ohio**

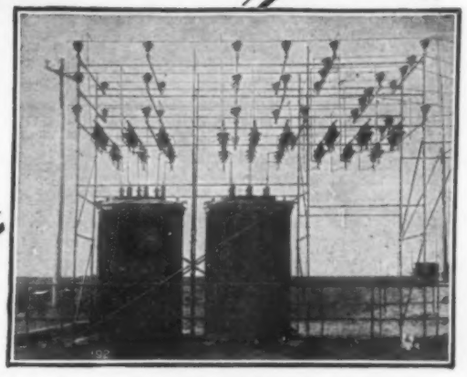


Fine engineering, high class workmanship and excellent materials make more consistent performers out of—

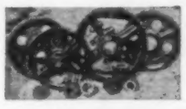
Moloney Transformers

Low densities in iron and copper, large cooling surfaces, liberal insulation and great mechanical strength are well known features which have made them so thoroughly satisfactory in the field.

Moloney Electric Company
Main Office and Factories:
St. Louis, Mo.
Sales Offices in Principal Cities

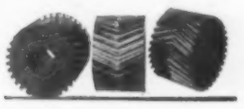


Herringbone Mill Pinions

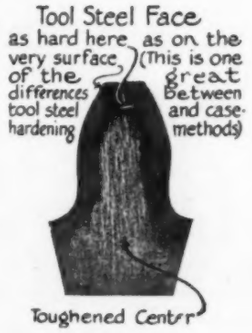


Motor and Crane Gears

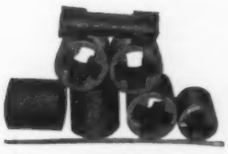
Mill Table Gears



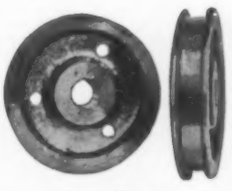
Herringbone Gears


Tool Steel Face
as hard here as on the very surface (This is one of the great differences Between tool steel and case-hardening methods)
Toughened Center

Cincinnati "Tool Steel" gears outlast 8 to 10 Untreated and are much stronger

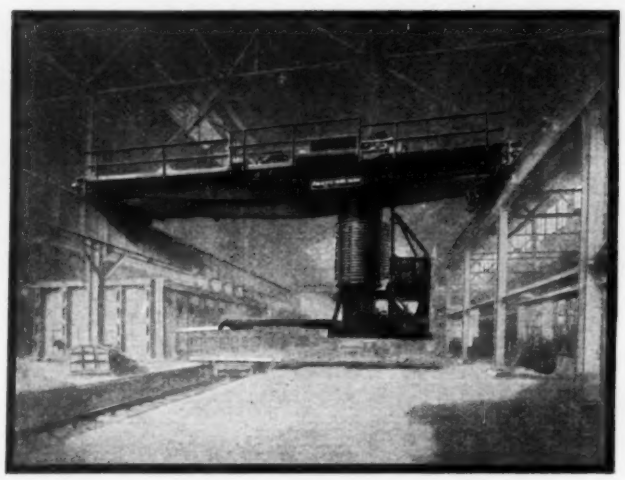


Coupling Boxes and Spindles



Crane Wheels

The Tool Steel Gear and Pinion Company
CINCINNATI, OHIO



Morgan 5-Ton, 45'-0" Span Overhead Revolving Type Billet Charger

The World's Standard

Morgan Equipment has won the title, "The World's Standard," because it measures up so fully to the heavy, exacting demands of the steel industry.

Morgan Equipment has been so closely allied with the steel industry for so many years that it just naturally seems to be a part of it.

You'll find Morgan Equipment profitably busy in most every steel plant.

The Morgan Engineering Company

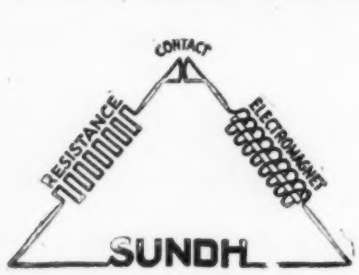
CHICAGO
122 So. Michigan Ave.
NEW YORK
120 Broadway
PITTSBURGH
1420 Oliver Bldg.

ALLIANCE, OHIO

Designers, Manufacturers and Contractors

Electric Traveling Cranes, Rolling Mill Machinery, Ordnance Steel, Shipbuilding and Forging Plants Complete, Rock Crushers, Special Machinery for Any Purpose

Locomotive Repairing and Rebuilding



Steel Men!

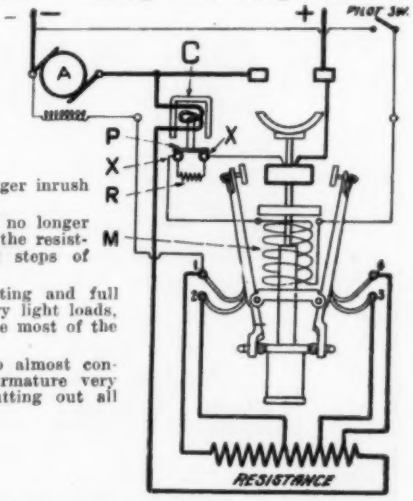
Isn't this what some of you wanted, as brought out in your discussion of control in your Journal of November, 1921? A control that would have definite time limit modified with current limiting element?

You want a starter to obey its real function, don't you? i. e., to start and accelerate a motor by cutting in resistance, then out, in the shortest possible time in relation to the load. You want the motor to "mote" if it's at all possible to do so, whether the voltage is high or low, or whether there is excessive friction on a cold Monday morning. If the first current inrush does not start it, the next one may. If we can't get it to start on small amounts of current, we want to provide automatic means of increasing the current or power so that it will start, provided that no one has placed a crowbar in between the gears or there happens to be a short circuit. In that case, overload circuit opening devices take care of the condition.

We have been using this method since 1911. On large size motor starters, reversing and non-reversing, we use the multiple level starter as a pilot relay whose multi-contact energizes large shunt wound switches for cutting out starting resistance.

The action of this control is easily understood from the diagram, and the following description of operation:

The relay C is in series with the armature only during the starting period and is normally set to operate at about 130% of normal current. When the current in the armature of the motor equals or exceeds this setting on the starting inrushes, the armature of the relay lifts the plate P from the two contacts XX and by this action inserts the resistance R in series with the solenoid coil M of the automatic starter. The resistance R can be made to have a resistance so that when inserted in the circuit of the coil M (by action of excess load on the armature of motor at start) it partly destroys the effective magnetic pull of coil M and prevents the cutting out of any more resistance in the armature circuit, but at the same time there is sufficient magnetic pull to lift the core very slowly so that in time, even with the insertion of this resistance in the magnet coil circuit, the next succeeding step of resistance will be cut out, giving a larger inrush current to the motor.



Under normal conditions as soon as the current in the armature reduces to about normal, the coil C can no longer hold up plate P and it consequently drops, thus closing the circuit across contacts XX, and short circuiting the resistance R, allowing coil M to be again fully energized and to act with full power, thus cutting out succeeding steps of resistance quickly.

The retarding action caused by excess load on coil M may take place during any interval between starting and full running position. The time of the dash pot is generally set for a minimum of 1½ seconds, which in case of very light loads, the cutting out of resistance would take approximately this time, since the series relay coil C plate XX, would be most of the time short circuiting the resistance R.

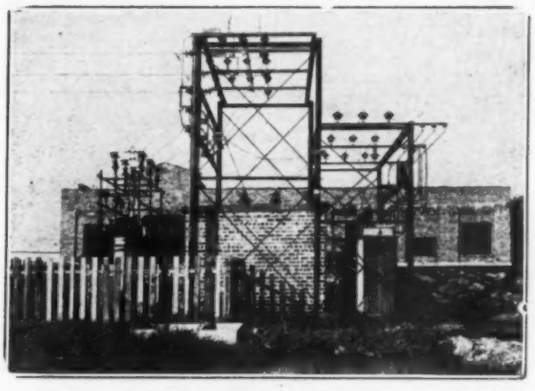
Under abnormal, extremely heavy loads, where the series coil C would lift its armature and hold it up almost continuously, thus inserting all the resistance in the coil, R circuit on automatic starter coil M would lift its armature very slowly against the action of the dash pot and light pulling force, and may take up to 15 seconds before cutting out all resistance.

The resistance R may be made of a value as to either increase or decrease the pull of magnet coil M.

Write for Catalog.

SUNDH ELECTRIC COMPANY Newark, N. J., U. S. A.

The REAL STANDARD "UNIT TYPE"



Unit Type Outdoor Sub-stations Are Complete

Why Steel Mill Engineers Specify Unit Type

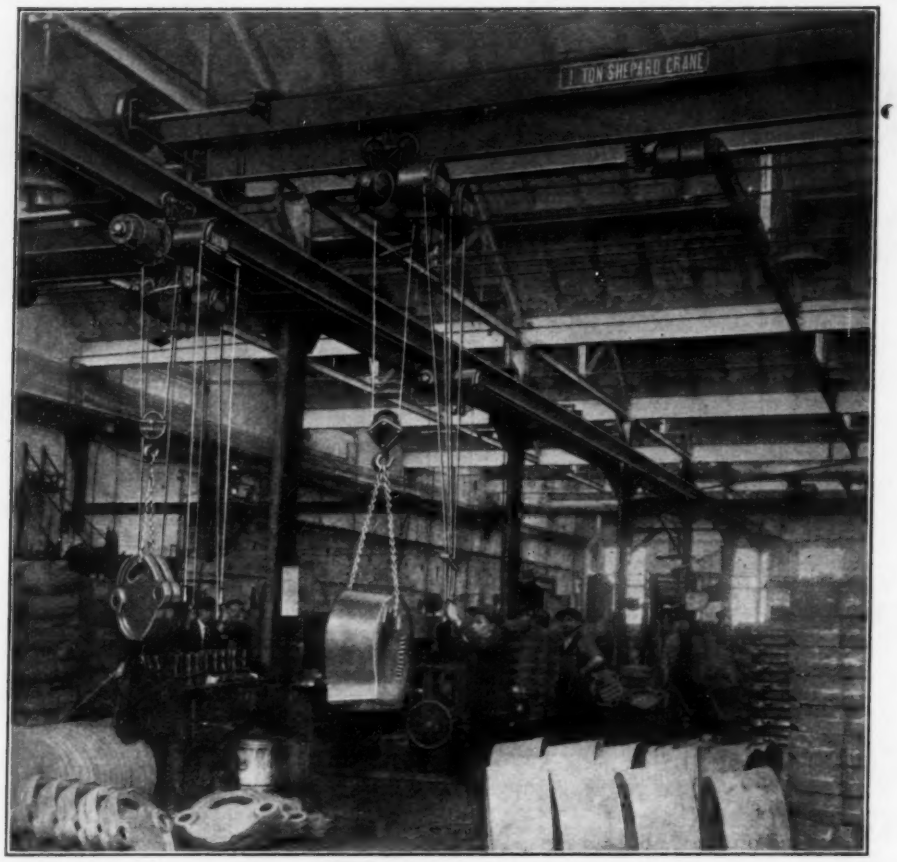
STEEL MILL engineers are more and more specifying Delta-Star material. Very naturally a variety of reasons enter into the selection of **UNIT-TYPE** by these engineers. One is strongly influenced by the design, another by its simplicity, another by its all-round usefulness and reliability.

But in every instance there is one reason standing out boldly above all, constituting by all means the most important factor in every sale, and that is the pronounced and unmistakable value that **Unit-Type** equipment represents under present conditions.

YOU BETTER BUY THE BETTER BUY—UNIT TYPE

Delta-Star Electric Co

346 Union Arcade, Pittsburgh **1333 Real Estate Trust Bldg., Philadelphia** **2433-61 Fulton St., Chicago**



This view shows Shepard Floor Control Electric Hoist operating on Shepard Single I-Beam Crane, also three Shepard LiftAbouts.

"We don't lose a minute with Shepards"

This is the report from the Lord & Burnham Company of Irvington, N. Y. This shop is completely equipped with Shepard Electric Hoists.

Carrying heavy castings around the shop, to and from machines for each operation—everywhere Shepard Hoists have displaced the slow, costly method of hand and truck moving. There's not a minute lost in idle machines.

Precision of control is one feature of the "Shepard" which makes it such a great asset in the shop. The operator has full control, and can accurately place a load.

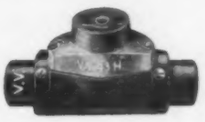
Write for descriptive information of Shepard Electric Hoists as used in many industries.

SHEPARD ELECTRIC CRANE & HOIST CO.
382 Schuyler Ave., Montour Falls, N. Y.
Branches in Principal Cities.
Member Electric Hoist Mfrs.' Assn.

382

REG. U.S. PAT. OFF.

SHEPARD
ELECTRIC CRANES & HOISTS



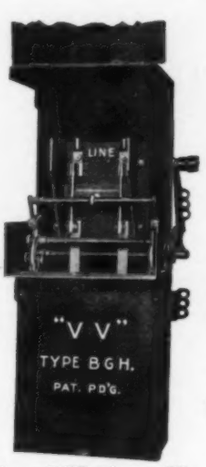
"THE SUPER SAFETY SWITCH"

TYPE BGH

Built to Stand Under the Most Severe Conditions

QUICK POSITIVE MAKE INSTANTANEOUS FULL BREAK

All Grounded Parts Shielded by Fibre Barriers
Greater Break Distance and Extra Spacings



Type BGH shows Fibre Barriers in Switch Compartment — sides removed.

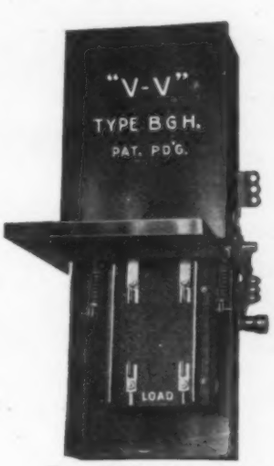
This Switch
Cannot Be Teased
or
Left in Partial Contact

Two-Three-Four
Pole

30-60
100-200
Ampere

250-500
600
Volt

USUAL "V-V" SAFETY FEATURES



Type BGH shows Fibre Barriers in Fuse Compartment.

For Capacities Above 200 up to 1500 Amperes We Embody the Same Insulation Features in our TYPE DFH Which Is Front Operated

Prices on Application.

V. V. FITTINGS COMPANY

New York
50 Church St.

PHILADELPHIA, U. S. A.

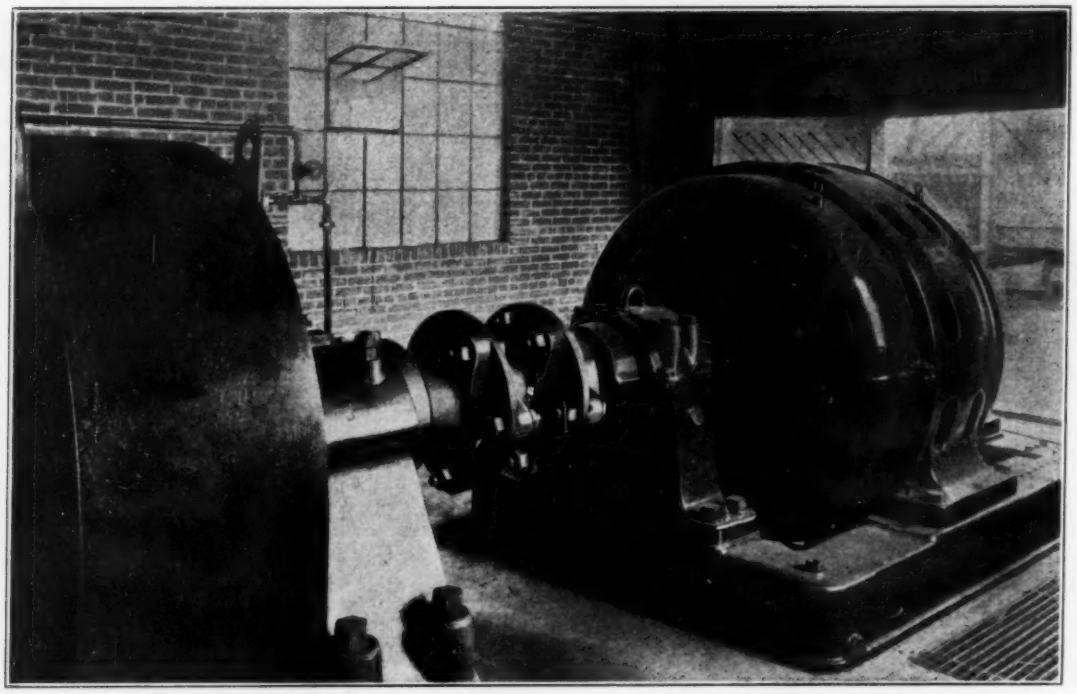
Chicago
532 So. Canal St.

Pittsburgh Representative
P. H. Schaum
933 Liberty Ave.

Cleveland Representative
S. R. Shepard
1240 Ontario St.

THOMAS FLEXIBLE COUPLINGS

FOR HEAVY DUTY ROLLING MILL SERVICE



A Thomas Mill Type Flexible Coupling Connecting 1,000-H.P., 375-R.P.M. Motor Through Gear Drive to 16″ Merchant Mill at Burlington Steel Co., Hamilton, Canada

Let our Engineers who have wide experience in the application of Flexible Couplings for Main Roll Drives acquaint you with the wonderful possibilities of this economical modern Rolling Mill Coupling.

THOMAS FLEXIBLE COUPLING CO.

MAIN OFFICE AND WORKS—WARREN, PA.

Sales Offices: New York, Chicago, Cleveland, Philadelphia, Pittsburgh, Boston, St. Louis

C. H. Hills, Special Representative, Springfield, Mass.

The Giant Hand

That Reduces Your Handling Costs

Without chain slings, hooks, or buckets, the C-H "Red" Magnet like a *giant hand* picks up and conveys scrap, pig iron, bars, plates, kegs of nails and rivets, pipe, rails, castings—anything of iron and steel.

The big savings possible through use of these giant hands have become more generally recognized.

In a modern warehouse a C-H Magnet loads 12,000 pounds of plate on trucks in 10 minutes—in another plant $168.00 is saved per week in labor cost alone using a C-H Magnet to handle round steel bars.

In foundry service C-H Magnets unload from cars, break up scrap, convey material to cupola, carry hot castings to tumblers and finished castings to delivery floor, cars, and trucks. In one plant the saving of eight hours' time in loading and unloading the annealing furnace made unnecessary the contemplated purchase of another furnace.

Elsewhere the *giant hand* on a short run hoist released 10 wheelbarrow men for other work. A scrap iron company saved the entire cost of a C-H Magnet and overhead crane in one year. Wooden kegs of steel rivets are handled with a C-H Magnet—floor space saved, materials piled higher and floor trucking eliminated.

C-H "Red" Magnets operate indoors or out, in bad weather or good—winter or summer. Made in various sizes and lifting capacities; details in Publication 3015.

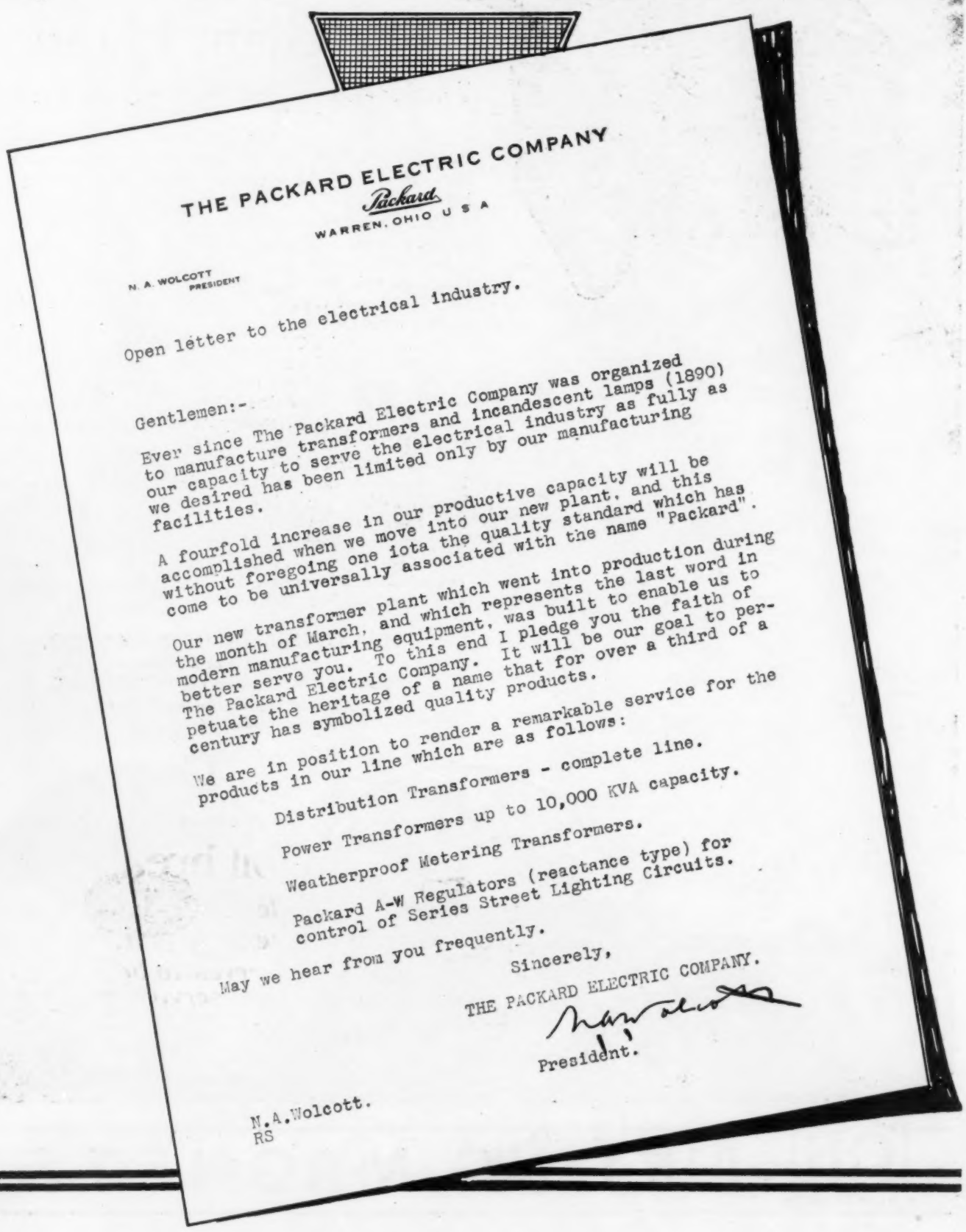
THE CUTLER-HAMMER MFG. CO.
Magnet and Clutch Department
Works: MILWAUKEE *and* NEW YORK
Offices and Agents in Principal Cities
Northern Electric Co., Ltd., Canada

C-H
CUTLER-HAMMER

LIFTING MAGNETS

New Transformer Plant –

PACKARD ELECTRIC COMPANY QUADRUPLES TRANSFORMER CAPACITY



THE PACKARD ELECTRIC COMPANY

Packard

WARREN, OHIO U S A

N. A. WOLCOTT
PRESIDENT

Open letter to the electrical industry.

Gentlemen:-

Ever since The Packard Electric Company was organized to manufacture transformers and incandescent lamps (1890) our capacity to serve the electrical industry as fully as we desired has been limited only by our manufacturing facilities.

A fourfold increase in our productive capacity will be accomplished when we move into our new plant, and this without foregoing one iota the quality standard which has come to be universally associated with the name "Packard".

Our new transformer plant which went into production during the month of March, and which represents the last word in modern manufacturing equipment, was built to enable us to better serve you. To this end I pledge you the faith of The Packard Electric Company. It will be our goal to perpetuate the heritage of a name that for over a third of a century has symbolized quality products.

We are in position to render a remarkable service for the products in our line which are as follows:

Distribution Transformers - complete line.

Power Transformers up to 10,000 KVA capacity.

Weatherproof Metering Transformers.

Packard A-W Regulators (reactance type) for control of Series Street Lighting Circuits.

May we hear from you frequently.

Sincerely,

THE PACKARD ELECTRIC COMPANY.

President.

N.A.Wolcott.
RS

AIR!

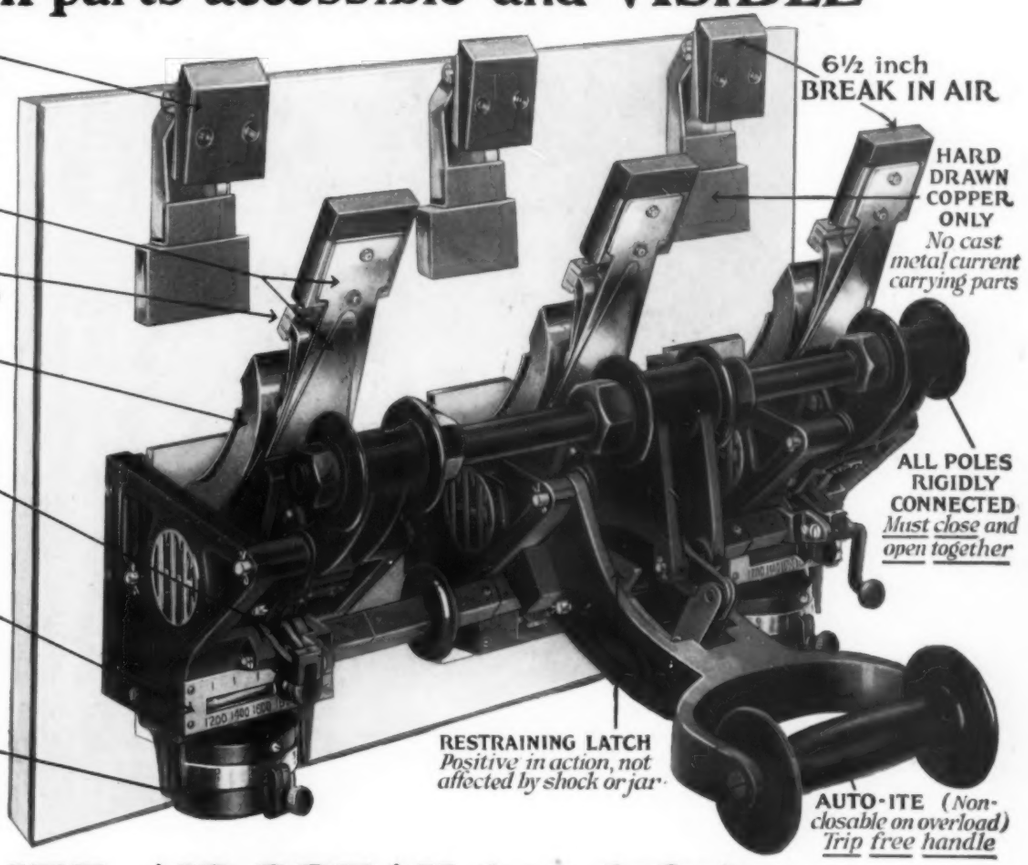
CIRCUIT BREAKERS

For Alternating Current

600 VOLTS OR LESS

Give protection without complication

All parts accessible and VISIBLE

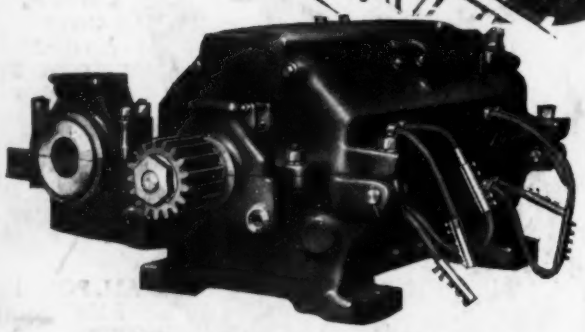

COPPER JACKETED PRESSURE CARBONS
For initial contact and final break
Mechanically strong
Electrically perfect
PHOSPHOR BRONZE CARBON SUPPORTS
HEAVY METALLIC SECONDARY BREAKING CONTACTS
LAMINATED BRIDGE
Each leaf individually formed - Heavy even pressure on every Lamination
CLOSING TOGGLES
Afford heavy contact pressure with easy closing
OVERLOAD
Direct acting. Long scale calibration. No relays or series transformers
DALITE
(Direct acting time limit) feature. Adjustable from zero to maximum time. No relays
6½ inch BREAK IN AIR
HARD DRAWN COPPER ONLY
No cast metal current carrying parts
ALL POLES RIGIDLY CONNECTED
Must close and open together
RESTRAINING LATCH
Positive in action, not affected by shock or jar
AUTO-ITE (Non-closable on overload)
Trip free handle

I-T-E AIR BREAK has definite advantages not present in the oil breaker

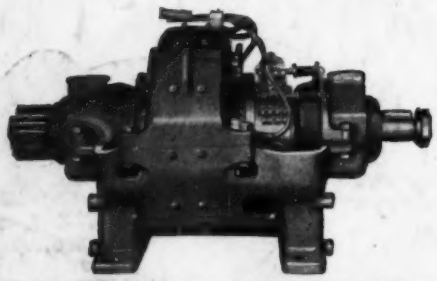
1. *No oil — to leak, carbonize, burn or explode — Just air.*
2. *No tanks to conceal anything — or the lack of it.*
3. *No cells — nothing which needs or deserves to be imprisoned — Just a faithful and efficient servant.*
4. *Inherent simplicity — with resulting low cost of installation and maintenance.*

The CUTTER COMPANY

ESTABLISHED 1888 PHILADELPHIA



Standard Enclosed Frame DC Mill Motors, Type MD—range from 4 to 175 h.p., 230 and 550 volts.



Standard Open Frame DC Mill Motors, Type MDS—range from 6 to 210 h.p., 230 and 550 volts.

Specially Designed Motors Adaptable to All Work

THE increased production of higher quality at lower power cost, obtained throughout steel mills by the use of G-E motors, is due to the complete adaptability of these motors to the work through series, compound or shunt winding.

For operating screw down tables, the MD motor is especially applicable. This motor used for this work has a heavy mechanical design throughout, a large foundation area, heavy self-contained countershaft brackets, parts easily replaced, small diameter armature to allow rapid reversals, superior commutation, heat-resisting insulations and totally enclosed frame.

A complete line of standard control, either manually or magnetically operated for all classes of steel mill auxiliary drive has also been developed. This equipment assures close power input control without continuous racking of the entire mechanism.

Additional details will be promptly supplied by the nearest G-E office. Write for Bulletin 48121.1A.

General Electric Company
Schenectady, N. Y.
Sales Offices in all Large Cities

43B-515

GENERAL ELECTRIC